PROCEEDINGS 38TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOLUME V

1918

BALTIMORE, MD.
THE WAVERLY PRESS
1918

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VOL. 5 NO. 1 MARCH, 1918

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OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED QUARTERLY BY THE

AMERICAN WATER WORKS ASSOCIATION

AT 2419–21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912

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The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

VOL. 5 MARCH, 1918 No. 1

REPORT OF CITY PLANNING COMMITTEE[1]

In its report for this year, your City Planning Committee decided to consider only two of the items suggested for study in the report given at the last Annual Convention. These two suggestions related to the collection of data on the design of water-works structures, with the special point in view of making them sightly and pleasing, and incidental to this point, in so far as it relates to lands around pumping stations, reservoir sites, etc., their use for park purposes for the general public.

In connection with these studies an endeavor was made, as far as possible, to ascertain the extra cost involved in arranging the structures to conform with aesthetic and park requirements.

Following out this idea a postcard was addressed to a large number of the members of the American Water Works Association, asking them to submit photographs and data as to costs along the lines suggested. Many such were received and the Committee desires to express its appreciation of the assistance rendered it in securing photographs and information from members of the Association and will appreciate further contributions along the same lines.

It is believed that the kind of work contemplated for the City Planning Committee of the American Water Works Association is

[1] Read before the Richmond Committee, May, 1917. The committee submitted a large number of views relating to the subject, of which it is practicable to reproduce but a few.

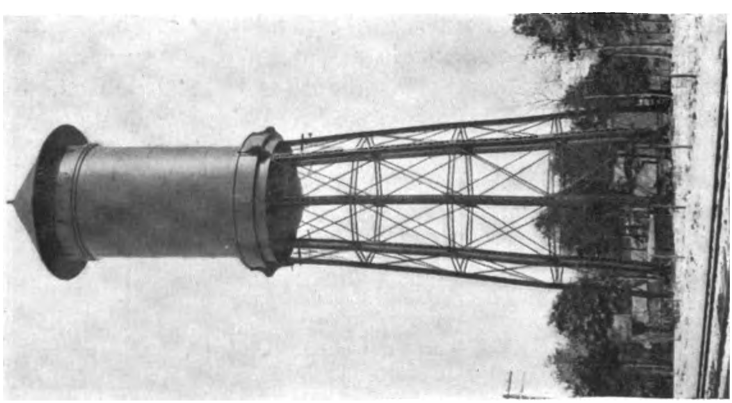


FIG. 1

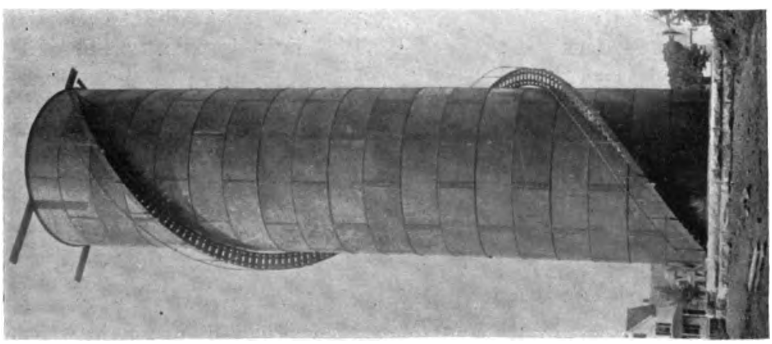


FIG. 2

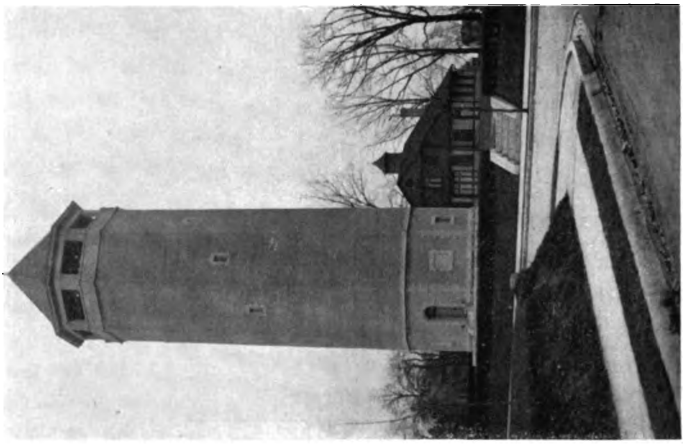


FIG. 3

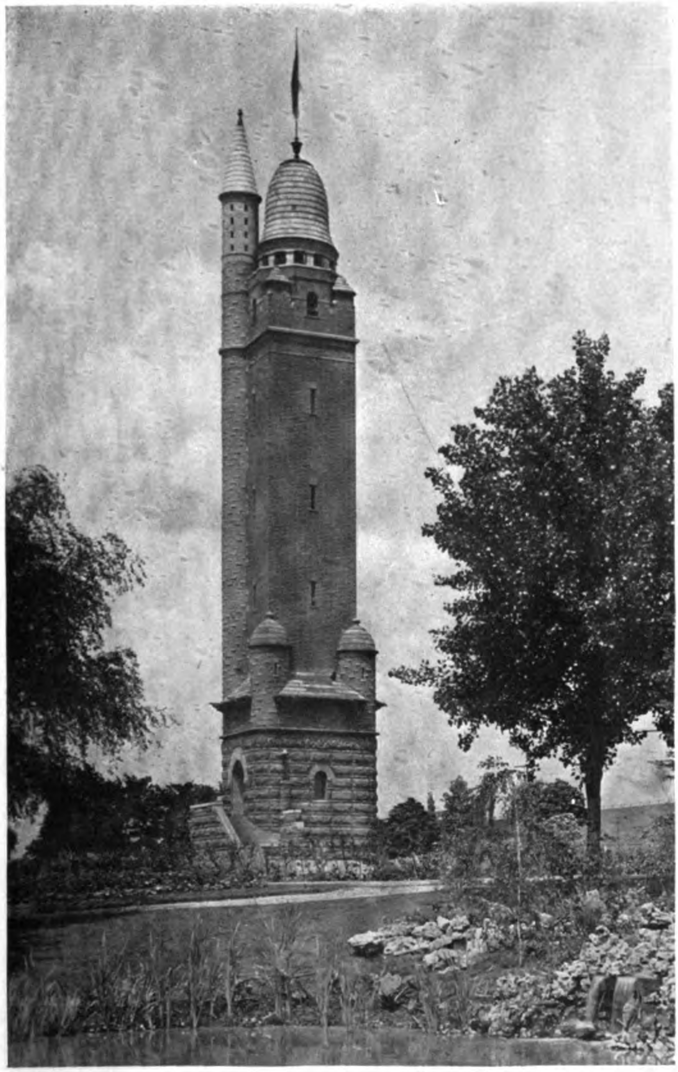


FIG. 4

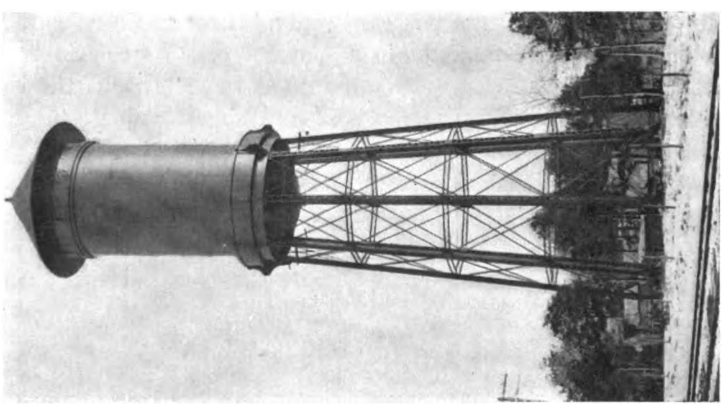
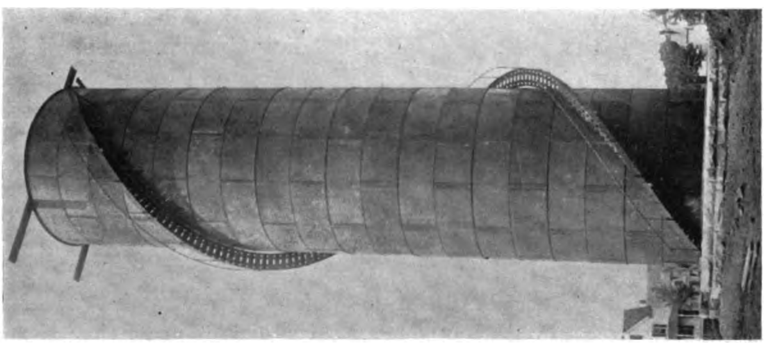


FIG. 1



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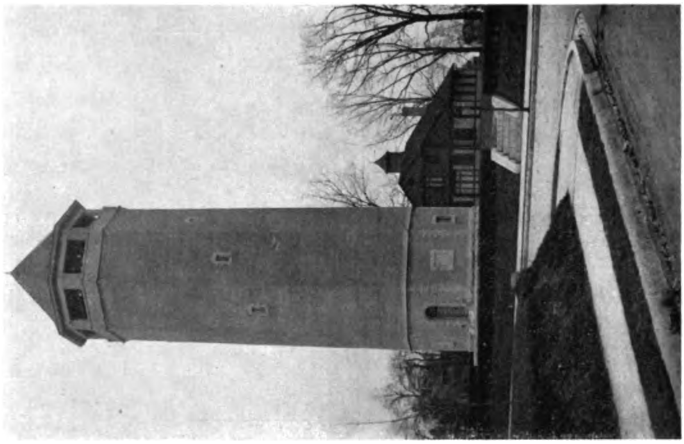

FIG. 3

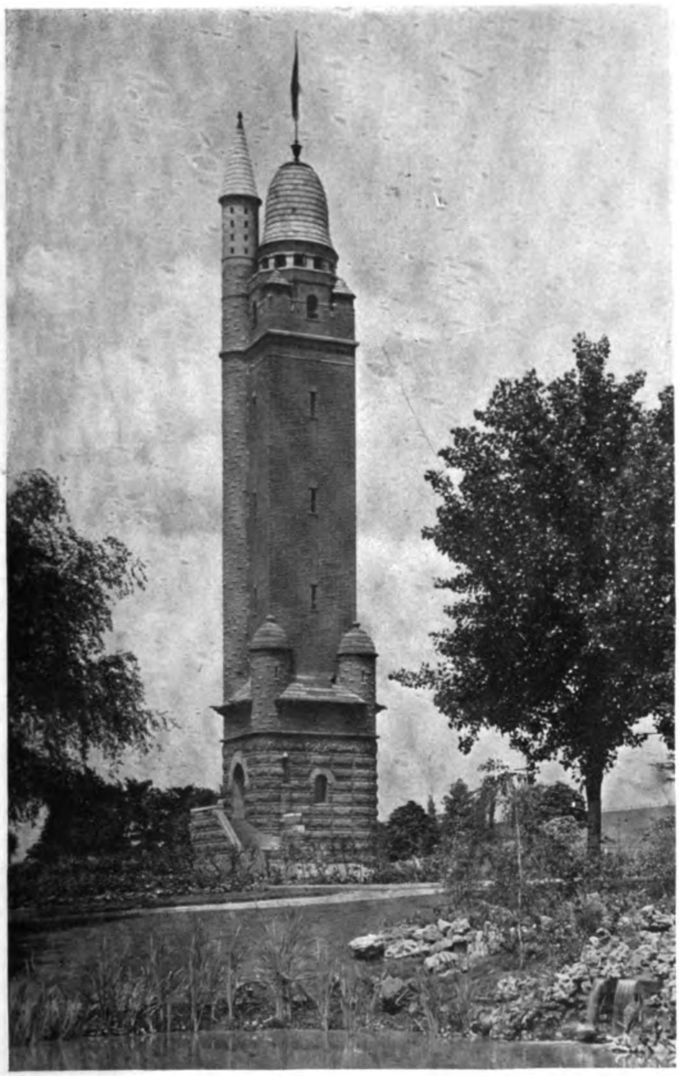

FIG. 4

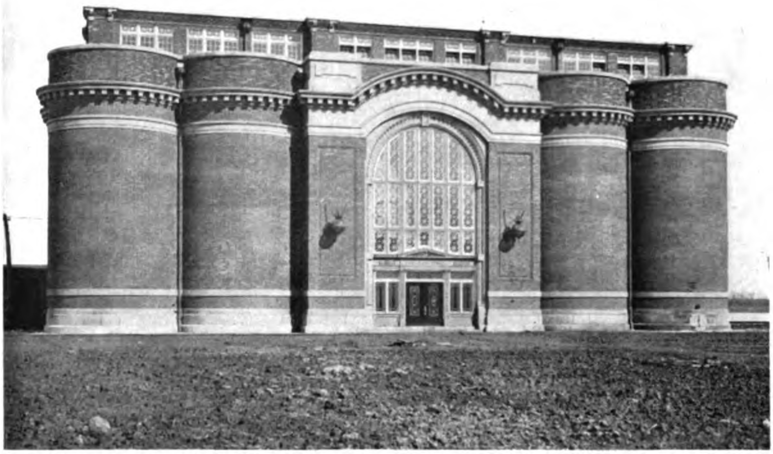

Fig. 5


Bluff Cottage—Manager's Residence
Public Utilities Co.,
Mt. Carmel, Ill.

Fig. 6

FIG. 7

FIG. 8

FIG. 9

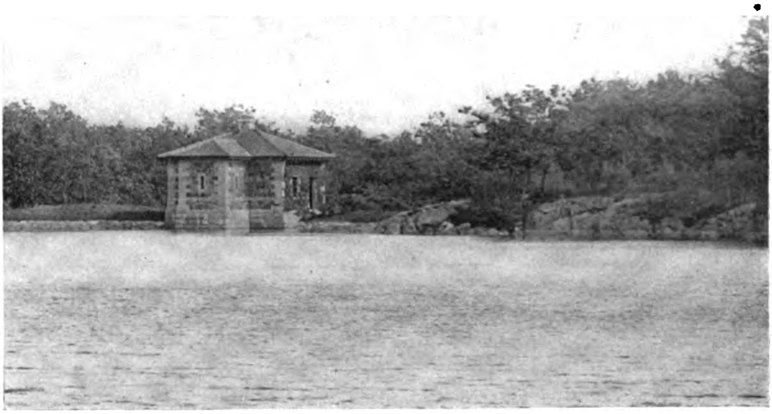

FIG. 10

FIG. 11

FIG. 12

such that a committee on that subject should be continued by the Association.

A special selection from among the photographs and slides has been made to illustrate special points relating to this subject.

Figure 1 submitted by Nicholas S. Hill, Jr., shows an elevated tank in a residential community. The cost of improving the outline added $1200 to the cost of a plain tank. The proportionate increase is obviously very small and apparently well worth the extra amount involved. Almost any community would be willing to spend such an amount with the corresponding benefit.

Figure 2 submitted by Nicholas S. Hill, Jr., shows a standpipe which would have marred the landscape of a residential section but which was enclosed at an additional cost of about $15,000, as shown in figure 3. Residents can hardly object to such a point of interest in their landscape.

A somewhat more elaborate design for a water tower is shown in figure 4, submitted by James W. Armstrong, at the Crompton Hill Reservoir of the St. Louis Water Works. This tower with its setting is an exceptional example, perhaps a little ornate, but otherwise admirable.

Another example of special architectural treatment of water works structures is shown in figure 5, submitted by James W. Armstrong, showing the Coagulating House, Chain of Rocks, of the St. Louis Water Works. The frank incorporation of the tanks into the exterior architectural design is much to be commended and the interesting design secured demonstrates the general architectural canon that the essential nature of the structure should be displayed and not concealed.

That care in building design and landscaping is believed advantageous both by public utility companies as well as municipal commissions, is shown by the statement of P. Barnhard, Manager of the Public Utilities Company of Mt. Carmel, Ill., concerning the manager's residence, Bluff Cottage, shown in figure 6, concerning which he says, "It pays to dress up and beautify the surroundings. We have had many compliments from both local people and visitors."

Exceptional views of the possibilities which have been worked out along landscape and parking lines are shown in figures 7 and 8, submitted by Mr. Armstrong, of a roadway along a hill side in the Chain of Rocks Park under the jurisdiction of the St. Louis Water

Works, and of the grounds around the settling reservoirs of the Cincinnati Water Works at California, Ohio.

That such parking can be combined with water protection of reservoirs even when they are extensively patronized, is shown in figure 9, submitted by Mr. Armstrong, of Porter Cove, Spot Pond, at Boston, Mass.

The possibilities of successfully fitting architectural structures into the landscape is demonstrated in figure 10, also submitted by Mr. Armstrong, showing how the boulder face walls of the gate house of the Fells Reservoir at Stoneham, of the Boston, Mass., water system fits into the adjacent rocky landscape.

Another example is illustrated in figure 11, submitted by Nicholas S. Hill, Jr. This is "a simple concrete, reservoir gate house with good lines, on a main thoroughfare in a high-class residential section." The architectural treatment added substantially no cost to the structure.

That even such a usually obnoxious structure as a chimney can be made relatively innocuous is shown in figure 12, submitted by Mr. Hill, illustrating "a pumping station in the center of a large city near the entrance of a park."

Many other examples might have been cited, those selected being believed to represent typical examples. Additional illustrations, particularly where the special costs of securing improved results are obtainable, will be greatly appreciated by the committee.

LEAD WOOL*

By R. J. Thomas

In calling attention to lead wool as a material for calking joints in cast iron pipes, the author does not claim to bring up a new subject; but it does seem at this time, when the price of pig lead has risen so enormously while lead wool has not advanced materially, that it is a favorable opportunity to make tests to ascertain whether or not it will pay to use lead wool to the exclusion of cast lead.

The material most used to calk joints in cast iron pipes is cast lead. The yarn or oakum is loosely pounded into the bell around the spigot and then about 2½ inches of cast lead are poured into the joint. The lead shrinks when cooling and there is no contact between the iron pipe and the upper or bell side of the lead, so that it becomes necessary to calk the lead in order to swell it sufficiently to close this space caused by shrinkage. It is manifestly impossible to pound this lead hard enough to make it expand for more than ½ inch, leaving about 2 inches of lead which are absolutely useless in so far as strength of the joint is concerned. It has some strength in holding back the yarn, but for all practical purposes it would be just as well to fill the joint with yarn and then run in ½ inch of lead, only that this would not give enough metal to expand properly and it would be pushed into the spigot rather than expand.

Every superintendent is familiar with the delays of the melting pot; the danger of spilling hot lead, and the waste which comes from handling it. The author has seen a melting pot containing about 200 pounds of metal from which at least 25 pounds of dross had been taken, so that 10 per cent was wasted in this way. He has seen trenches held up because it was too cold to pour the joints or because rain had filled the bells with water. So without intending to disparage the material which has been used for so many generations in water works practice, it is believed that there are so many points in favor of lead wool that it may pay to discuss the subject at this time.

Assume that a bell-and-spigot joint is a stuffing box and the

* Read at the Richmond Convention, May, 1917.

advantage of the yarn is the flexibility which it gives to the line. Now in using lead wool, one of the most essential features is the calking of the yarn into the joint as tight as possible. It has been said that joints which have been calked with a pneumatic hammer and stood a hydraulic pressure of 1800 pounds showed, when the joint was cut to demonstrate its character, the yarn bulged up like rubber, proving that the whole line must have been under tension and that any expansion or contraction could readily have been taken up. It therefore seems obvious that the great advantage coming from the use of lead wool is due to the fact that as the strands of lead wool are pounded into the bell, the compression on the yarn is constantly increased and as good an effect is produced as by using a rubber packing held in place with a clamp.

The impression exists that lead wool joints are too expensive to make and that the first cost is prohibitive. No doubt a lead wool joint cannot compete with a cast lead joint in point of time in making. It can, however, save fully 25 per cent of the lead used, which at the present time is quite an item, but it does require more yarn and certainly requires more labor to make it satisfactorily than a cast lead joint. But consider just what this labor is of which more is required. For instance, a gang of calkers laying 36 inch pipe can lay 10 or 15 lengths a day. With a cast lead joint these 15 joints can be poured in an hour, and with a pneumatic hammer they can be set back ½ inch, with two calkers, in eight hours. This would give joints without the yarn being compressed and with just half an inch of lead holding at the joint. Some of these joints at 150 pounds pressure would leak and the chances are that three out of fifteen joints would be imperfectly run, and would have to be made over.

If the same joints were made with lead wool it is manifestly true that no two calkers can yarn and calk fifteen 36 inch joints in one day satisfactorily. The best two calkers can do would be seven joints in one day of ten hours, and they would be exceptional workers, and five 36 inch joints a day is about the best that two calkers can do. It therefore would seem on first observation that with 36 inch pipe three times the number of calkers will be required to do the work with lead wool as with cast lead. As a matter of fact the lines of pipe where 15 lengths of 36 inch pipe can be placed in position in a day are very unusual and it is very rare indeed for the average calker to do more than four hours of useful work out of a

day of eight or ten hours. The rest of the time he is waiting for the lead to melt or the pipes to be put in position or for sundry other causes. It is obvious, therefore, that while theoretically it will take three times as long to make the lead wool joint, practically this is not the case. When it is considered that the lead wool joint will be capable of standing a hydraulic pressure even as high as 3600 pounds to a square inch, that the yarn will be under compression, and that the leakage from breaks will probably be eliminated, there is an advantage in favor of the lead wool joint which cannot be too strongly insisted upon.

The author wishes to quote here from the report of Committee on Cast Iron Pipe Joints (1915) of the American Gas Institute, Mr. Walton Forstall, author:

> The joints were made with 20-inch special bells and tested in a testing machine of 500,000 pounds capacity at the University of Pennsylvania and were subjected to alternate compression and tension. The tests were based on the fact that a 20-inch cast iron main underground subjected to a temperature change of 30° would be stressed 125,000 pounds and would be subjected to alternate compression and tension due to the seasonable changes. In these tests the joints were made up as carefully as possible, the bells being of the standard A. G. I. depth. During the alternate compression and tension stresses placed on the joint, air pressure of from 2½ to 4 pounds was kept on the joint and they were tested for leaks by using a trough made of putty around the joint and filling the trough with water. This was a more positive method of testing than with soap suds.
>
> The cement joint, which was made in the usual way and not according to the committee's specification, as this work was undertaken before the final specification was prepared, failed under a tension strength of 40,000 pounds, approximately one-third the safe load. The cast iron joint made with the standard method with yarn and cast lead properly calked failed after six reversals at about 25,000 pounds. Lead wool joints with 1 inch, 1¼ inches and 1¾ inches of lead wool calked with a pneumatic hammer in the usual way remained tight for 50 reversals with a maximum of 80,000 pounds tension and compression with a movement greater than would be experienced by the main underground.
>
> The combination cement and lead wool joint consisting of back yarn, a band of cement which was allowed to set and then lead wool calked in front proved to have about the same efficiency as the lead wool and yarn alone.
>
> These experiments were continued with cement, cast lead, lead wool, and combination lead wool and cement with the results that the lead wool or combination cement and lead wool, calked with a pneumatic hammer, was shown to be the most satisfactory under laboratory conditions.

It would seem from this report and from the general experience

of the gas companies using lead wool, particularly now that the price of lead wool is more nearly approaching that of pig lead, that this is a good opportunity for water works men to decide whether this material shall come into more general use. The author has cited its use on 36 inch mains to show just wherein the great diversity of cost is most apparent. He would next call attention, to the manner in which lead wool has been most successfully employed by the Detroit City Gas Works. Its practice is to calk three lengths of 16-inch pipe together before lowering them into the trench. This reduces the cost of bell holes two-thirds and enables the calkers to work ahead, so that the pipes are ready before the trench is dug. It is said that this was so successfully done in Detroit that more than six weeks of time was saved on one pipe line. On 6-inch pipe, six lengths may be calked together and the pipe rolled into the trench. Generally ropes are employed to lower the pipe, but the pipe may be thrown right into the trench without fear of breaking the joint. It is then caught up with chain-falls and drawn back to fit the bell. It has been said that the calkers working outside of the trench do nearly three times the amount of work without fatigue as in it, that men seek the job and that their health is so vastly improved that the old distaste for calking disappears and the calker seeks the job rather than having to be coerced into doing the work.

The Water Department of Springfield, Mass., laid several years ago a line of 42-inch pipe, using lead wool for the joints. Three hundred joints were made in all. This pipe, although carrying 150 pounds pressure, has proved absolutely tight. The Metropolitan Water Department of Massachusetts has also laid a line of 42-inch pipe, using lead wool exclusively on the joints.

Lead wool has been before the public for more than ten years and the price maintained on it has been due to some patents which are now expiring, so that its high price compared with pig lead will no longer be so conspicuous. It therefore seems to the author that superintendents, engineers and contractors should decide for themselves whether or not the lead wool joint has sufficient merit to warrant putting in the extra time which is required to make it, and, perhaps, at some greater investment on the first cost.

The author would quote from a paper by Mr. Walter Hole, presented at San Francisco, September, 1915.

Reasons of greater strength of lead-wool joints. The greater strength of the lead wool joint is due to two factors. First, the greater compactness of

the yarn backing of the joint. In making a lead-wool joint the yarn is driven back by each successive ring of lead wool until it becomes quite compact and hard. In the run-lead joint it is more loose and soft. In one case the yarn alone will withstand a pressure of 100 pounds per square inch, while in the other it will not withstand half as much. In the second place, although the run-lead ring may be denser in itself than the lead wool, it does not fill the socket so closely throughout its depth. The run-lead is poured into the socket recess very hot. On cooling, it contracts and shrinks away from the interior surface of the socket. No amount of calking will restore the ring throughout its full depth to gas-tight contact with the two iron surfaces. Under a microscope the effect of calking could be seen to extend to only $\frac{5}{8}$ inch from the face of the joint. Compare with this the case of a lead-wool packing, inserted and calked up strand by strand in closest possible contact from back to front and around the whole circumference of the joint, and it is bound to be the more gas-tight and stronger of the two.

Crystallization of lead ring. Several interesting points in connection with a run-lead joint are brought out in the cut [not reproduced]. The section taken was from one of the joints tested for specific gravity, and pickled in nitric acid to throw up the crystals. The section is exactly 2 inches long and the vertical lines divide the joint into four equal portions. In the portion at the back of the joint and up to the halfway line the crystals are quite normal. Then for $\frac{3}{8}$ inch there is an area of disturbed crystals due possibly to the presence of vapors and to interrupted crystallization. For $\frac{5}{8}$ inch from the face of the joint the effect of calking is more or less clearly marked. The cooling line running horizontally through the center of the lead ring is very noticeable for 1 inch from the back, but becomes much less distinct towards the face, disappearing altogether as the face of the ring is reached. As previously suggested, shrinkage towards the center, which produces such a line, is one of the reasons for the essential inferiority of the run lead ring.

The author will not take up time with considering this material for remaking cast lead joints, or stopping leaks, and many other things for which it is well adapted. In New England a water works superintendent would not feel at ease if he did not have a stock of lead wool for repairing leaky joints and making new joints in especially bad places. But from what he has read and from observation, the author believes lead wool has a broader field of usefulness and that it will bear deep study.

LEAKAGE FROM VITRIFIED PIPE USED TO CONVEY WATER UNDER A LOW HEAD[1]

By William W. Brush

It is frequently of greater value to the water works profession to record the troubles that have been experienced than to describe work which has satisfactorily met all requirements. The Bureau of Water Supply of the Department of Water Supply, Gas and Electricity of the City of New York, has had to repair numerous leaky joints on a vitrified pipe line that was constructed to deliver water under a maximum head of not over 5 pounds per square inch. The following description of this pipe line, the leaks repaired, the tests made of joint material, and the conclusions reached, may be helpful to those who have a similar problem in the future.

General. The Borough of Richmond had an inadequate and unsatisfactory water supply prior to the introduction of the Catskill water, which was made effective in January, 1917. The average daily consumption in the Borough is 12,000,000 gallons. To meet the growth in consumption and to lower the overdraft at existing stations, an additional supply of some 6,000,000 gallons was planned as far back as 1910. A driven well system was to be established along what is known as Southfield Boulevard, a broad public highway running along the southeasterly side of Staten Island. The carrying out of this plan was delayed by various causes, and the new development was not completed sufficiently to be utilized until the spring of 1915. The plant is briefly described as follows:

The central station, known as the Grant City station, has three steam-driven pumps, with a capacity of 12,000,000 gallons, and two electric generators. The supply is derived from five groups of wells, one located at the central station, with two to the northeast and two to the southwest thereof. Electrically driven centrifugal pumps draw the water from the wells and deliver it into collecting lines, through which it flows to a pump well at Grant City station. The four auxiliary stations are operated by power furnished by the

[1] Read before the Richmond Convention, May 10, 1917.

central station, the yield of the individual stations varying between 750,000 and 3,000,000 gallons daily. For the two southwesterly stations, a cast iron distribution main has for the time being been used as a collecting main. The two northeasterly stations deliver their supply through an 18-inch vitrified pipe line 7460 feet in length. This pipe line, where it joins the cast iron line from the southwesterly stations, enlarges to a 24-inch vitrified line 557 feet long, which extends to the central pump well. Here the water is drawn by the steam pumps and delivered into the distribution mains under a pressure of about 110 pounds per square inch.

The department proposed to construct the entire collecting line of cast iron pipe, but owing to the short period that would probably elapse between the completion of the development and the introduction of the Catskill water, it was necessary to reduce the construction cost to a minimum. The utilization of an existing distribution main, which was not immediately required to deliver water, satisfactorily solved the problem of a collecting line for the southwesterly section. The substitution of 18-inch vitrified pipe for 16-inch cast iron pipe for the northeasterly section reduced the estimated cost from $27,000 to $20,000. At the time the substitution of vitrified pipe for cast iron pipe was recommended, I. M. de Varona, then chief engineer of the Bureau, noted that a risk of excessive leakage was taken, but based upon previous experiments, it was concluded that the joints could be made sufficiently watertight to permit the pipe line to serve its purpose satisfactorily. There was no fear of the pipe itself being of insufficient strength to withstand the pressure, which was estimated at a maximum, under working conditions, of about 5 pounds per square inch.

Vitrified pipe line. The 18-inch pipe was to be the usual sewer pipe 1½ inches thick, with the depth of hub 3 inches, with a maximum variation from these dimensions of 2.5 per cent. The inside diameter of the hub was to exceed the outside diameter of the spigot by not less than 1 inch nor more than 1½ inches. The inside of the hub and the outside of the spigot were to be corrugated. The specification for forming the joints is as follows:

After each length of vitrified pipe has been laid and brought to true line and grade and the spigot fully entered into the hub, a gasket of packing yarn, dipped and saturated in cement grout, which shall have been mixed not more than thirty minutes previously, shall be firmly rammed into the joint with a hardwood calking tool. . . . .

The joint material shall be a compound which shall not deteriorate when submerged in fresh or salt water or in solutions slightly alkaline or acid. It shall melt and run freely at temperatures not greater than 250°F. It shall adhere well to the glazed surface of earthenware pipes. . . . .

The hubs and spigots shall be thoroughly cleaned before the joint is poured and as dry as reasonably possible. The compound shall be heated in a kettle to a temperature of about 400°F. It shall be frequently stirred. Material which has once cooled shall not be reheated. . . . . The compound shall be poured in a full stream so as to fill the entire space before it becomes cool. The gate shall be slightly to one side of the crown of the pipe, and the compound poured so that it will run in one direction only around the joint. . . . . The depth of the joint shall be about 2 inches and shall not be less than 1¾ inches. . . . .

The pipe was to be laid to grade on the bottom of the trench, except where the earth would not properly support it, when either timber or concrete supports were to be furnished. The pipe was laid, as far as possible, with a minimum cover of 3 feet.

This contract was awarded to Joseph Johnson's Sons at an estimated cost of $19,209.37, which also included the furnishing, delivering and laying of some 1200 feet of cast iron pipe, mainly 20 and 12 inches in diameter, the construction of the pump well, and other miscellaneous work, as well as the vitrified pipe. The price submitted for furnishing, delivering and laying the 18-inch vitrified pipe was $0.90 per lineal foot; for 24-inch vitrified pipe, $1.25 per lineal foot; and for earth excavation and backfilling, $0.50 per cubic yard. These were considered fair prices for this portion of the work. The contractor was ordered to begin work on September 28, 1914, and was allowed seventy-five working days for completion. The need of the additional supply was urgent, and the work was prosecuted from early in October until January 16, the pipe laid each month being as follows: October, 1540 feet; November, 3016 feet; December, 2985 feet; January, 500 feet.

The cold weather interfered with the work, as did also the water in the trench, due to the ground water level being above the pipe invert at some places. The contractor selected for the joint compound an asphaltic mixture known as Filtite A, which was the material previously used in tests made by the Bureau and which had been successfully used in sewer work in Brooklyn. The laboratory report on a sample of the compound was as follows:

Examination shows this material to be a compound of asphaltic base with petroleum residue containing about 50 per cent of mineral matter.

It is apparently unaffected after forty-eight hours immersion in fresh and salt water, and in weak acid and alkaline solutions. Previous experiments upon similar materials indicate that it will not be materially affected.

At 205°F. it is a viscous liquid, flowing somewhat slowly, like cylinder oil.

After two hours exposed to a temperature of 220°F. it loses only 0.11 per cent in weight.

After the contract was completed the following analyses were made:

The following are the results of analyses of three samples of pipe joint compound, received at the laboratory April 20, 1915. The samples were marked as follows:

No. 73. Filtite A. Sample of pipe joint compound used on contract 1356; sent by order of the Chief Engineer.

No. 74. Jointite material used at Grant City, S. I.

No. 75. Jointite material furnished by the Pacific Flush Tank Company, for test at North Portland Avenue Yard, Brooklyn.

No. 72. For comparison) Filtite, made by Pacific Flush Tank Company, taken from barrel on work at Grant City P. S., October 8, 1914, on Contract 1356.

	NUMBER 73	NUMBER 74	NUMBER 75	NUMBER 72
	per cent	*per cent*	*per cent*	*per cent*
Analysis of compound:				
Clay (ash by ignition)	62.07	61.27	54.42	49.73
Bitumen	37.93	38.73	45.58	50.27
Analysis of bitumen:				
Petrolene	70.50	70.33	69.02	
Asphaltene	29.50	29.67	30.98	
Fixed carbon	8.67	7.75	11.61	

The analyses show that the compound is not entirely uniform; the bitumen in sample No. 75 is somewhat harder than the others, as shown by the fixed carbon. There does not seem to be sufficient difference between the samples to account for the failure of the work.

The engineer in charge of the field work reported that the joints were made in accordance with the specifications; that the joints were carefully cleaned after the cement saturated yarn was rammed into place; that the contractors objected to the use of this yarn, as it caused trouble and delay; that the contractors were experienced in the use of the joint compound; and that the work was carefully

performed in accordance with the specifications. The engineer further reported that his examination showed that in spite of the careful cleaning of the joints there was evidence that the cement adhered to the compound and interfered with the adhesion of the asphaltic joint material to the surface of the pipe.

Leakage at joints. When the laying of the pipe had been completed the infiltration of ground water was noticed. The flow was gauged at the central pump well in the latter part of February and early in March, and found to average during a three-day test 43,470 gallons per twenty-four hours. This was equivalent to 163 gallons per joint per twenty-four hours. The seepage clearly indicated that leaks would be found.

On April 7, this line was placed under test, the head being about the working head, and at 22 points in a distance of 1261 feet, water showed on the surface. Here the boulevard is on a fill over a swamp and the foundation for the pipe is consequently somewhat unstable. When the leaky joints were examined the conditions disclosed might be described under these three heads:

First. Where a separation existed between the joint compound and the barrel of the pipe or between the joint compound and the hub. This separation varied from the merest hair-line opening to an amount which would admit the passage of a knife blade.

Second. Where the joint compound had started to blow out, in general more at the bottom of the pipe than at the top, varying from the merest indication of starting to cases where pieces of the compound were ready to fall out.

Third. Where the joint at the bottom was entirely blown out. In some cases the pieces of joint material were thrown out by the laborers in excavating.

On April 14, the contractor had re-run the leaking joints and on April 15, the pipe was again subjected to test by operating both pumps in the most easterly station. Fifteen leaks developed on this test. After a discussion as to the responsibility of the contractor to repair all leaks, under a clause which required a year's guarantee of all the work, he made the repairs, beginning June 4, finding 58 joints to be replaced.

Leaks have continued on this line since then up to the shutting down of the plant in February, the record being as follows:

	1915	1916	1917
January		19	4
February		26	6
March		36	
April		10	
May		11	
June		*	
July	11	19	
August	4	36	
September	4	66	
October	3	29	
November	8	6	
December		24	

* End of maintenance period by contractor.

The contractor made all his repairs by removing the joint material and re-running the joint. The department men tried various schemes, the one mainly used being to drive the joint material into the hub, calk in lead wool, and then place a concrete block around the joint, as shown in figure 1. The repaired joints, in general, did not leak again. Practically no trouble was occasioned by split pipe, only one or two being found in the whole line.

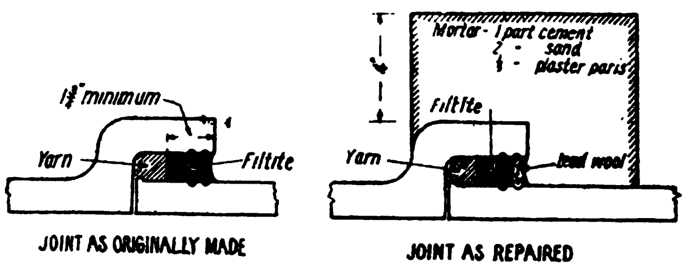

Fig. 1. Types of Joints

Experimental tests of joints. In 1912 the Bureau had tested 12-inch vitrified sewer pipe, using the G. K. compound and Jointite, the latter being the predecessor to Filtite, and practically the same material. This test showed the joint would stand 29 pounds per square inch. At the same time joints made of plain yarn, with yarn soaked in cement grout and with lead wool, gave very unsatisfactory results. At an earlier date cement joints poured also leaked freely.

After the leaks were discovered two tests were made, one in the field at Grant City, and one at the Portland Avenue yard in Brooklyn.

The Grant City test, which is illustrated by the photograph, was as follows: On May 19, 1915, work was started, the three pipe joints being calked with grout soaked yarn, after which the joint space was thoroughly cleaned and dried. The joints were then run with the joint compound. On May 22, the joint runners were

FIG. 2. CLOSE OF TEST AT GRANT CITY PUMPING STATION

removed from joints at 9 a.m.; the joints were carefully examined and found to be good.

At 10.30 a.m. the men started filling the test pipes with water, with the air valve open, under a head draft. The pipes were full at 11.05 a.m. and air valve was closed 12.05 p.m.

		feet
12.40 p.m.	No leakage, head increased to	8
1.10 p.m.	No leakage, head increased to	9
1.47 p.m.	No leakage, head increased to	10
2.20 p.m.	No leakage, head increased to	11
2.55 p.m.	No leakage, head increased to	12
3.15 p.m.	No leakage, test suspended due to rain, and air valve opened.	

The pressure of 12 feet was again put on May 26, and continued without leakage until May 27, when both joints were leaking. The leakage reduced from a maximum rate for each joint of about 24 gallons per twenty-four hours to about 10 gallons for one joint and 2 gallons for the other, the test continuing until June 14, when the pressure was slowly raised to 35 pounds, and held there for thirty-five minutes with a leakage from one joint of 232 gallons per twenty-four hours. The pressure was then raised to 40 pounds, when a pipe split.

Two test lines, each consisting of three lengths of 18-inch standard deep and wide socket vitrified pipes with bulkheads at the ends, were set up at the North Portland Avenue Yard. The arrangements of these test lines is shown in figure 3.

The joints of one of the test lines were poured with material

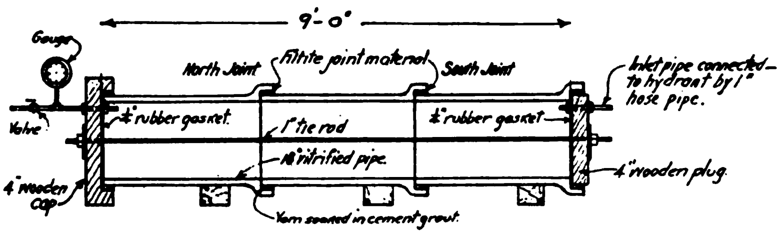

FIG. 3. NORTH PORTLAND AVENUE YARD TEST

received from Joseph Johnson's Sons and the joints of the other line were poured with similar material furnished by the Pacific Flush Tank Company.

The joints were made in accordance with the specifications, a jute gasket dipped in cement grout being used at the back of the joint. The material received from the Pacific Flush Tank Company was first poured. Before pouring, the cement remaining on the surface of the southerly of the two joints in this line was brushed off the pipe so as to leave the pipe clean. The cement was allowed to remain on the surface of the pipe and spigot of the north joint. It was attempted, as specified for the Southfield Boulevard contract, to pour the material through a gate located a little to one side of the top of the pipe, allowing the joint material to flow down and around the pipe and up on the other side. On the joints where the Pacific Flush Tank Company's material was used, this was not

accomplished, the material flowing both ways from the top of the pipe. On the north joint, the clay gasket used to confine the joint material broke through several times during pouring and time necessarily elapsed between successive pourings while the clay was being repaired. The south joint was provided with a rubber hose gasket and no difficulty from breaking out of the material was encountered.

On the line in which the contractor's joint material was used, hose was used as a gasket and the joints were poured, as specified, the material flowing from one side only.

On April 21, these joints were tested under water pressure. At 9 o'clock both pipes were filled to the top with water, and the bulkheads allowed to swell so as to become tighter. The pipe containing the Flush Tank Company's material was tested first, beginning at about 9.40. First water was allowed to flow rapidly into the pipe, the outlet being wide open. Probably a small amount of pressure was developed, although none showed on the gauge. The north and south joints showed slight leakage near the top, but leaks in both cases appeared to be due to shrinkage of the materials.

At 9.50 a pressure of 5 pounds per square inch was applied. The leakage increased somewhat and a small new leak developed in the north joint. At this pressure the south joint leaked at the rate of about 110 gallons per twenty-four hours and the north joint about 540 gallons.

At 10 o'clock, a pressure of 10 pounds per square inch was applied. A new leak developed in the north joint, which is the one in which there was difficulty during pouring. The north joint leaked about 2900 gallons per twenty-four hours; the south joint about 180 gallons.

At 10.06, a pressure of 15 pounds was applied. There were then four decided leaks in the north joint and the leakage was about 4300 gallons per twenty-four hours. No new leaks developed in the south joint and the leakage was not measured.

At 10.11, a pressure of 20 pounds was applied; a new leak developed in the south joint. It was found at 10.14, on account of leakage that it was impossible to hold the pressure at 20 pounds and it dropped to 19 pounds. At that time there was a leakage of about 720 gallons per twenty-four hours from the south joint.

The pressure was taken off at 10.15. The north joint was calked with a wooden calking tool on both sides of the pipe just above the horizontal axis where leaks had developed. On the east side, the joint was found to be hollow, due probably to trouble in pouring.

A pressure of 5 pounds was put on the pipe line again and the leaks were practically the same as before calking.

An attempt was then made to calk the north joint with 5 pounds pressure on the pipe; no improvement in watertightness was apparent. As far as could be observed, calking resulted in failure, since it broke the bond of the material with the pipe and failed to compress the material so as to make it tight against the socket and spigot.

None of the joints in this line showed any signs of movement under 20 pounds pressure.

The line in which the contractor's joint material was used was then put under test at about 10.20. The north joint had been leaking slightly at the bottom since 9 o'clock, when the water was first put into the pipe and before any pressure was put upon it.

At 10.27, the water was passed rapidly through the pipe and both joints showed some very slight leaks.

At 10.30, 5 pounds pressure was applied to the line. The north joint leaked about 48 gallons per twenty-four hours and five minutes later the leakage had increased to about 180 gallons per twenty-four hours. In the south joint there was very little change from the condition under no pressure and the leakage was about 135 gallons per twenty-four hours.

At 10.39, the pressure was increased to 10 pounds. The leakage in the north joint increased at the bottom and side, but no new leaks formed. In the north joint, the leakage was about 270 gallons per twenty-four hours. In the south joint there was no change in the number of leaks, the leakage increasing to about 270 gallons per twenty-four hours.

At 10.45 o'clock the pressure was increased to 15 pounds. No new leaks developed, but the leakage increased in the north joint to about 360 gallons per twenty-four hours, and in the south joint to about 630 gallons.

At 10.50, the pressure was increased to 20 pounds, and at 10.52, while an attempt was being made to measure the leakage, the south joint moved out at the bottom so that no further tests on this line were possible.

The pipe in which the contractor's joint material was used was then broken and the joints removed for examination. It was found that the south joint which failed was deficient in depth at the bottom. The yarn gasket had apparently not been driven back into

the socket sufficiently to permit the full depth of the joint to be poured. The remaining joint appeared to be satisfactory.

The north joint in the line in which the Flush Tank Company's material was used, was then cut out with a cold chisel. This joint was, of course, known to be defective on account of trouble during pouring. It was found that hollow spaces existed in the joint material. There seems, however, to have been no lack of adhesion to the joint, except where the joint had been calked so that the joint material was broken.

Conclusions. The experimental work and the field results showed that the vitrified pipe would safely stand low pressures, say under 25 pounds per square inch, that none of the joint compounds were successful in preventing leakage, but that fairly satisfactory results could be obtained by thoroughly cleaning the joints before running the joints. The use of cement soaked yarn appeared to be detrimental in its effect on watertightness of the poured joint.

The Bureau has been experimenting with calked cement joints for cast iron pipe, following the instructions given by Clark H. Shaw in his paper presented on April 18, 1917, before the American Society of Civil Engineers. These joints have been highly successful under test pressures up to 300 pounds per square inch. There seems to be no good reason why a calked cement joint in a vitrified pipe would not be watertight up to the pressure the pipe would safely stand if care is exercised to calk only to an amount that the hubs will stand without cracking. Experiments along this line are to be undertaken by the Bureau in the near future.

THE DIFFERENTIATION OF BACTERIA OF THE COLON-AEROGENES FAMILY[1]

By William Mansfield Clark

When the author was asked to present a paper before this meeting he gladly accepted for he felt that some of the results which Mr. Rogers and himself had obtained in various studies of the so-called colon group of bacteria may be of some use not only in future studies of water supplies but in rapidly and accurately meeting some of the problems which will arise in connection with the water supplies of our camps and our armies in the field. At the same time the author is painfully aware that he is not familiar with the details or the special problems of water bacteriology and he, therefore, begs indulgence while he reviews some studies in which he has been particularly interested.

For a long time a distinction has been made between B. coli and B. aerogenes, but in the heterogenous collection of organisms which were fished from feces, water, milk, etc., it was not always easy to make a clear distinction by the tests at hand. The reason is perfectly plain.

If we study not only the more modern work but especially the researches of Harden it is evident that the products of fermentation by B. coli on the one hand and B. aerogenes on the other are very similar and differ chiefly in the quantitative proportions.

The quantitative differences in gas production were recognized by Theobold Smith and upon these differences, Dr. Smith established the use of his fermentation tube. Because the characteristics studied differ only in a quantitative way, while the method involves sources of serious analytical error, the Smith fermentation tube has been of very limited usefulness. Harden, Harden and Walpole, and Thompson established somewhat more accurately the gas ratios but it remained for Keyes and Keyes and Gillespie not only to furnish reliable data for B. coli but to frame the method of gas iso-

[1] Read before the Chemical and Bacteriological Section at the Richmond Convention, May 10, 1917.

lation which has proved so useful in the more extensive investigations by Rogers and his collaborators.

When bacteria of the colon-aerogenes family are grown in bulbs evacuated by a mercury pump and the CO_2 and H_2 liberated in the anaerobic fermentation of dextrose are collected with the aid of such a pump and analyzed accurately the ratio CO_2/H_2 has been found to be a most valuable means of differentiation. We have now the analyses for about 660 cultures.

In their study of cultures isolated from milk and milk products, Rogers, Clark and Davis found that approximately half gave a low gas ratio $CO_2 / H_2 = 1.06$. The others gave decidedly higher and more variable ratios. Taking up a search for possible sources of these two groups, Rogers, Clark and Evans found that of 150 cultures isolated from bovine feces all but one were of the low ratio type. Where, then, are the high ratio organisms to be found? All possible sources are of course not known, but in a study of 166 cultures isolated from grain, it was found that 150 were of the high ratio type. Recently it has been found that high-gas-ratio cultures may be isolated from both bovine and human feces by special methods, but that the predominant type found in both human and bovine feces are of the low-ratio type.

The potential sanitary significance of such results is perfectly obvious. It will perhaps seem more pertinent if we recall that Rogers, following the course of several streams, found the low-ratio colon cultures increasing in relative numbers with the entrance of sewage and decreasing in relative numbers as the streams purified themselves and passed on into cleaner surroundings.

The gas analysis methods employed are necessarily laborious and time consuming and therefore not appropriate for routine work. But fortunately a test has been developed which correlates with the gas ratios. The history of the development of this test would lead into some technical details which can be appreciated only by a careful study of the published data, but the principles involved may be outlined as follows:

In its fermentation of dextrose, B. coli does not cease its activity with the production of any definite quantity of acid but only when the actual ionized acid, as measured by the dissociated hydrogen ions reaches a certain concentration. This value may be measured electrometrically by means of the hydrogen electrode, but for all ordinary purposes it is sufficient to measure it with an indicator.

The proper indicator to use in this instance is methyl red, which, if added to a culture of B. coli in definite quantity, will always assume about the same red color. It is evident that, if this lethal or limiting hydrogen ion concentration is to be reached, the culture must be furnished with sufficient sugar so that the acid formed therefrom may neutralize those substances in the medium which tend to combine with and suppress the dissociation of the acid. These substances are technically known as buffers. As the buffer action of the medium is increased, increasing amounts of the acid-forming sugar must be supplied. Now let the sugar content be adjusted to the buffer action so that B. coli can just reach its limiting hydrogen ion concentration. Under these circumstances, what will an aerogenes culture do? For every molecule of sugar that an aerogenes culture decomposes it forms very much less acid than a coli culture. Therefore, under the circumstances, an aerogenes culture can not overcome the buffer action of the medium. It can not reach that limiting hydrogen ion concentration characteristic of B. coli, its other activities are not suppressed, it continues to decompose what little acid has been formed, after a day or two it begins to make the medium more alkaline and the gross result is that the hydrogen ion concentration is very much lower than that of a colon culture. It only remains to make this difference evident to the eye. Since methyl red turns red in the one case and yellow in the other it is a suitable indicator for the purpose. Hence the test has come to be known as the methyl red test.

These are the principles involved. To apply them it was necessary to devise a medium in which the buffer action and dextrose content were properly adjusted. Such a medium is composed of 0.5 per cent K_2HPO_4, 0.5 per cent dextrose and 0.5 per cent Witte peptone.

This medium is inoculated with pure cultures of the organisms to be tested and grown five days at 30°C. To test the resulting hydrogen ion concentration it is necessary only to add some methyl red. Coli cultures are red to methyl red, aerogenes cultures yellow. This test was found to correlate perfectly with the gas ratios when typical organisms were used.

One of the essential components of this medium is Witte peptone. The war has made the price of this preparation prohibitive and therefore several workers have tried to substitute other peptones. Now there is no particular virtue in Witte peptone which makes it

necessary to use it in this instance, but it must be clearly emphasized that it takes part in the buffer action of the medium, upon the proper adjustment of which the very essence of the test is based. When, therefore, other peptones are substituted without any regard to the principle mentioned, uncertain results can safely be predicted. It has been a matter of great surprise to the author that several bacteriologists, without any regard for the very simple and essential principles of the method, have indiscriminately changed the composition of the medium. Apparently the question of economy or the mere curiosity to see what would happen had greater weight than the adherence to a scientific principle.

There is no apparent reason why peptone preparations other than Witte's can not be substituted provided the relation of the resulting buffer action to the sugar content is properly adjusted. But rather than work over this question again, Dr. Lubs and the author decided to devise a synthetic medium. The principles applied were the same. The proper buffer action was provided by the salts of phosphoric and phthalic acids and the nitrogen by aspartic acid. The relative proportions of these were so adjusted that they furnished not only the proper buffer action but also the proper initial hydrogen ion concentration, for it is now known that adjustment of the reaction of a medium by the old titration method has nothing but an empirical significance for particular media and that the only valid general method of adjustment is in terms of hydrogen ion concentration. Then, by trial, the proper dextrose content was fixed. The resulting medium is composed of 0.7 per cent anhydrous Na_2HPO_4, or 0.88 per cent of the salt which contains two molecules of water, 0.2 per cent KH phthalate, 0.1 per cent aspartic acid and 0.4 per cent dextrose.

Tests of 229 typical cultures of the colon aerogenes family have been made on this medium. The correlation between the differentiations so made and those made with the gas ratios was 100 per cent perfect.

The author has mentioned so far the tests made upon what have been called typical cultures. By typical cultures in this instance are meant those organisms whose gas ratios and gas volumes, when accurately determined, conform to one or the other of the two types of values which the study of some 660 cultures has clearly established as characteristic. From time to time there have appeared in the collections of the Bureau of Animal Industry or there

have been sent to the Bureau by others, cultures which in one way or another did not conform to either type. The methyl red test when applied to these cultures is more or less uncertain.

It is of course impossible to say how frequently or under what circumstances similar organisms will occur in the collections gathered in the routine examination of diverse waters. The Bureau's results indicate that they are comparatively rare and not likely to interfere seriously with sharp differentiations.

If these atypical cultures, which can not be definitely classified by any test known to the author, are excluded, there is a total of 374 cases in which the correlation between the methyl red test and the accurately determined gas ratio is perfect. As was pointed out in an earlier paper, a similar degree of correlation between any two tests used in the colon-aerogenes group was unknown.

Recently Levine in studying his collection of coli-aerogenes cultures discovered an almost perfect correlation between the differentiations made with the Voges-Proskauer reaction and those made with the methyl red test. By means of this correlation Levine was able to show that some of the conclusions regarding the distribution of these bacteria which had been reached in older studies with the Voges-Proskauer reaction were confirmed by the more careful work of Rogers and his collaborators.

According to Harden, "Voges and Proskauer's reaction . . . . appears to be due to acetyl methyl carbinol, which is formed by the action of the bacteria on the glucose of the medium. In the presence of potash and the air this is oxidized to diacetyl which then reacts with some constituent of the peptone water."

Since the revised medium described contains no peptone or any protein body, except such as may be formed by the synthetic action of the bacteria, it is necessary to supply such a substance if the Voges-Proskauer reaction in this new medium is to be observed. Harden and Norris have shown that various proteins and peptones react with diacetyl in the presence of alkali to give the eosin-like fluorescent color characteristic of this test. Since casein may easily be obtained in a pure state and reacts with diacetyl, it is a suitable reagent for this present purpose. It is added after the growth of the cultures together with the strong alkali and produces in the colorless synthetic medium an intensity of color which far exceeds that of any Voges-Proskauer reaction the author has ever seen in other media.

Colon cultures with low gas ratio do not give the reaction. High-gas-ratio cultures generally do.

For reasons which will be presented in detail in a forthcoming paper, the author does not place the reliance on this test that he does on the methyl red test. The chief reason is that in certain cultures the reaction is faint and fleeting, and may easily be missed. By means of very careful observations, however, for all the typical cultures tested a perfect correlation with the Voges-Proskauer test and the gas ratios has been established. This, then, furnishes three tests which correlate perfectly.

Correlations between the gas ratio and the Voges-Proskauer test have been established by Harden, Walpole and Thompson. Correlations between the methyl red test and the Voges-Proskauer test have been established by Winslow and Kligler, Levine, Hulton, Greenfield and Johnson. Dr. McCrady, of Montreal, has recently reported results which are in accord with the work mentioned.

Lastly, the Bureau of Animal Industry has established in its own work a correlation between the gas ratios, the Voges-Proskauer tests and the methyl red tests which leaves no doubt that the methyl red test is a simple, practical and reliable method for differentiating the two chief groups of the colon-aerogenes family.

Perhaps the author should here leave the subject for he has personally been concerned only with the development of the method and the technique of its use and not with interpretations of the sanitary significance of the results. But he desires to emphasize strongly a matter which, it seems to him, should be kept perfectly clear in any discussion of the merits of the test.

If it is desired to differentiate between the high and the low gas ratio cultures, between those two types which may be conveniently called coli and aerogenes, a reliable method will be found in the methyl red test. Of this there is no doubt. But the problems which water works managers face are more complicated. They are called upon not only to determine the flora of the waters placed under their care but also to interpret the sanitary significance of the flora that are found.

It is certainly suggestive to know that in the feces of man and domestic animals the methyl red positive type of the colon aerogenes bacteria is dominant, and in grain and certain soils the methyl red negative type predominates. But it is well to remember that a careful search will reveal B. aerogenes in feces and B. coli in virgin

soil and in waters situated far from the habitations of man and domestic animals.

It is evident, therefore, that the significant thing to look for is the relative numbers of each type in the material under examination, as Rogers did in his water work. In the extension of such studies, there will be involved several important questions, such as the relative rates of growth or destruction of each type when it enters waters of different chemical composition and of different physical conditions from various sources of pollution, and also the examination of yet unstudied potential sources of each type.

Perhaps such questions will have to be carefully and extensively investigated before one can draw very certain conclusions regarding the sanitary significance of the data furnished by the methyl red test, but it seems to the author that in the mean time the test should be included in the routine examination of water supplies for the following reasons: In the first place, it is as simple a test as any in use and at the same time is based upon phenomena the gross aspects of which are now known far better than are those of several other tests which might be mentioned. In the next place it correlates with other tests to a degree unknown among the tests formerly employed. Finally, laying aside any opinion that it may be used as a direct index of pollution, it does differentiate two very distinct types of bacteria which have frequently been confused in the routine tests of the past. It therefore gives the water works superintendent a better acquaintance with the flora of the supplies placed in his charge. Those who guard these trusts in more than a perfunctory manner probably depend upon such an intimate acquaintance to a greater degree than can be expressed in the formal terms of standard methods or court room pronouncements.

The author's belief is that the methyl red test will furnish the basis for some good guesses. It will at least be a valuable instrument for some practical researches.

DISCUSSION

F. W. Green: This subject of the hydrogen ions content, the neutrality of the media and the relationship between the two, appears to the speaker one of colloids. The condition of the media, as to whether these colloids are suspensoids or emulsoids, is a very important factor in the reaction, and, therefore, it is necessary to

take into account the electrical potential of the media. The speaker knows of no method of determining this and thinks that both in laboratory work and also in the reactions of the general supply this is a most important factor and should be taken into account. Tests should be devised whereby it will be possible to determine the amounts of colloids that are present and whether they are suspensoids or emulsoids.

JOSEPH RACE: Everyone who has had experience in water bacteriology must have a feeling of gratitude toward the workers at Washington for the able and painstaking efforts which they have made to elucidate the whole question of B. coli. The work which they have performed in the last two or three years has advanced our knowledge of B. coli more than all that has taken place during the last decade. The author has mentioned several important points and has discussed the technique in considerable detail. One point that he emphasized was the importance of the delicate adjustment of the buffer to the sugar, and to water works men it is important to know if the usual medium has this adjustment. The speaker believes it has not. The usual practice in the determination of type is to plate out from the liquid enrichment medium on the first signs of gas. That raises the question of the relative rate of reproduction of the various types in a given medium. Taking, for example, a fifty-fifty mixture of the fecal and grain types in lactose broth or bile; what will be the relative proportions after twenty-four and forty-eight hours? There is no guarantee that the colonies fished in the usual way are not all descendants from one common organism and the only accurate method for the determination of type is to plate out the original sample on a solid medium. On looking over his results for the last six to eight months it appears to the speaker that if gas is present in the fermentation after twenty-four hours the majority of the organisms are of the fecal type: after forty-eight incubation the majority are of the grain or negative methyl red type. This seems to indicate that the grain type is more resistant than the fecal type under the conditions obtaining in the fermentation tubes.

WILLIAM MANSFIELD CLARK: One of the accepted points in which colloids differ from crystalloids is the size of the particle. This carries with it certain accentuations of properties which are held

in common by both classes. Now it is true that in culture media we frequently have matter in the colloidal state but the essential point at issue is that these colloids act as neutralizers in essentially the same way as more familiar acids and bases. The neutralizing action of casein is an example. There are, of course, substances which differ from this in that the absorption of acids and bases is a phenomenon of surface condensation. Charcoal is not regarded as an acid or a base, and yet upon charcoal it is possible to have condensation of an acid and the resultant effect is as if the acid were neutralized. From the practical point of view the author thinks these particular explanations may be disregarded because there are methods which determine with reasonable accuracy, and simply, the actual hydrogen ion concentration of a medium; and so far as the author knows it is this value as determined by these methods which is found to be significant for the growth and metabolism of bacteria.

It would be very nice to be able to distinguish between the neutralizing effect of colloids as colloids and all other bodies which are acting by virtue only of their acidic or basic properties, but for most practical purposes it is at present unnecessary to make such a distinction in adjusting and testing culture media.

To determine by the simple methods at hand the hydrogen ion concentration which you actually have, whatever the conditions causing it, and to adjust media in accordance with the particular value which is found to be advantageous for the particular organism you are studying, is the first and necessary step.

The subject of enrichment media is one which we have not investigated, but there are involved certain theoretical considerations which it seems to the author ought to be recognized very clearly. B. coli has an optimum rate of growth slightly above the true neutral point, a hydrogen ion concentration represented by P_h 6.8 perhaps. On either side of that point the rate of growth will not decline rapidly at first, but regions may soon be reached where the rate will decline exceedingly rapidly. The relative rates of growth for B. aerogenes at different hydrogen ion concentrations has, so far as the author knows, not been studied and therefore he does not think it is possible to reach any definite conclusion regarding the relative increases in the number of each type when growing in enrichment media. Of course the question may have been attacked from an empirical point of view, with the medium strictly

limited to one composition and one reaction. No very useful generalization can be reached in that way.

In the study of all such problems it is exceedingly important, vitally important, to control the true reaction of the medium. This subject has been studied extensively by Dr. Lubs and the author, who have shown that the colorimetric method of measuring the hydrogen ion concentration of culture media can be used by any bacteriologist with ordinary chemical training. The author thinks the method will have to be applied before we know definitely where we stand in regard to several aspects of enrichment media.

In this connection the author desires to mention one incident. A certain official medium used for testing disinfectants contained a rich buffer in its content of beef infusion. It had been empirically established that this medium should have a certain "reaction" which, the author believes, was plus 1.5. Some one, the author does not know the history of the case and so may not state it with historical accuracy, some one thought it would be well to "simplify" the medium by substituting for the beef infusion 0.3 per cent Liebig's Extract. This was done, but the formula was left with the same degree of titratable acidity which had worked all right in the old medium. There was considerable wonder when it was found that the new medium would not work, but it was soon found why it would not work, for Doctor Phelps discovered that the new medium had a hydrogen ion concentration near the optimum acid agglutination point of B. typhi. By applying the rational method of adjustment they are now getting good results with the new medium.

The author might go on indefinitely with the citation of other cases. For instance, the product of one of our American manufacturers was seriously threatened because people insisted upon applying to media constructed with this peptone the old standards of reaction which had been empirically established for Witte peptone. Now that adjustments are made in terms of hydrogen ion concentration, as good and sometimes better results can be obtained with the American product.

In what degree the true reaction of an enrichment medium will influence the relative numbers of different bacteria in mixed cultures the author can not say, but he is sure little confidence should be placed in the process until this factor is experimentallv known.

LOWERING GROUND WATER LEVELS[1]

By Clarence L. Kirk

What the speaker has to say may not interest any one particularly unless he is engaged in laying pipe in a locality where the soil and subsoil are such as are found at the south end of Lake Michigan in Indiana, where there is nothing but sand. Several years ago, before the district there was very well sewered, the ground water stayed at just about the average surface elevation of the ground and it was very difficult to lay water mains. The sand with the water standing in its pores was a quicksand, about the worst quicksand imaginable. If the water could be taken out of the sand, the trenches would stand fairly well and little difficulty was experienced in the work.

A few years ago, when the speaker was actively in charge of the East Chicago plant, a little trench-draining apparatus with an ordinary diaphragm pump was devised. A 4-inch header about 19 feet long, with ¾ inch taps in it, was laid on timbers in the center of the trench, with well points connected to it in a staggered fashion. This header was connected to the pump and the water pumped out of the ground as in any permanent driven well installation.

Recently the man in active charge there has made quite an improvement. The apparatus that he uses consists of a header line about 100 feet in length, in which he uses, say, 30 feet of 3-inch pipe, 30 feet of 2-inch pipe and 40 feet of 1½-inch pipe. This is made up with reducing flanges where the change in size of pipe comes, and the men handle it one section at a time, if necessary, in moving. The far end of the header line is capped or plugged. On one side of this header and every 5 feet apart a 1-inch tap is made, screwing into this tap a nipple of 1-inch pipe threaded on one end and leaving the outer end so that it can be dressed down with a slight taper. This nipple need be only 5 or 6 inches long. The header is placed on the bank at one side of the trench. A 30-inch well-point 1¼

[1] An informal statement at the Richmond Convention, May 10, 1917.

inches in diameter is used, and to it is attached a 6-foot piece of 1¼-inch pipe. This is reduced to 1 inch for a hose connection, which is made permanent, the hose being about 4 feet long. After the trench has been dug as deep as possible without removing the water, the well points are jetted down by means of a piece of garden hose and a straight piece of ½ or ¾-inch pipe, using the regular pump for this purpose and water from a supply tank. After the points have been driven they are connected to the header by slipping the hose over the ferrule-like nipples. A 4-inch triplex pump connected to the header will produce a dry ditch in a short time and by having the outfit connected in this way it leaves full working space in the trench.

Frequent driving has a tendency to spoil the points. The mains are laid with about 5 feet of cover and the banks of sand will stand up without any sheathing at that depth. One of the peculiarities of the sand of that region is that before it has been disturbed in any way trenches cut in it will stand up well, but after it has been once disturbed and its original state changed, it will cave badly.

DISCUSSION

William W. Brush: On Long Island the Bureau of Water is drawing many millions of gallons of water from sand which is quicksand in appearance and action when saturated, but will stand up when dry. In Manhattan the subway contractors have generally adopted the sump method of draining wet trenches and those who have tried the well method have given it up. The speaker asked some of them why they did not use the latter method and was told that the sump method was much cheaper and gave entire satisfaction. The speaker has seen sand on Williams Street, New York, adjacent to buildings with very heavy foundation loads and where the sand with water in it was like quicksand, drained by putting in sumps surprisingly far apart and carrying these sumps down about 6 feet below the bottom of the subgrade of the subway. The question has therefore arisen in the speaker's mind whether the sump method of draining trenches in wet sand may not be better than the well method, although he has found the latter very satisfactory. In his experience, it has been impracticable to hold foundation planking in place in such soils without some method of draining the water out of the sand.

A. Prescott Folwell: The speaker would not encourage anybody from trying any promising method of keeping water out of trenches but he is unable to subscribe to the statement that the well method will be successful in any soil whatever, for he has seen trench work in porous gravel where the contractor was compelled to use a 6-inch and an 8-inch steam pump, working simultaneously, to keep the water down in a trench only 50 to 75 feet long for a sufficient time to permit laying sewer pipe. The speaker doubts that any number of well points would remove enough water from such a trench to keep it dry.

Dabney H. Maury: In a paper presented some time ago the speaker attempted to describe some of his engineering mistakes and one of those which had proved most costly was an attempt to put down a well by pumping from the inside. The devices described by the first speaker all aim at the same sensible treatment of the problem, namely, to remove the water without offering the sand an opportunity to flow into the excavation, for if the water is allowed to flow through the sand to the point where it is being removed it will certainly drag the sand with it. No matter how many times this warning is repeated, the mistake will probably be made many times by some of those who have been cautioned against it, although the blunder, often repeated though it is, causes much loss every year.

John W. Alvord: About ten years ago, in the construction of the sewerage system of Gary, Ind., very difficult running sand was encountered. The first contractor, using old-fashioned pumping methods of draining the ditches, ran heavily into debt and was greatly delayed in building a large main sewer. Later another contractor accomplished the construction of a similar main sewer about 17 feet deep by the well-point method of draining. The latter ditch was kept so dry by this method that the sand in the bottom of the ditch had about the same consistency as brown sugar. Rapid progress was made and the contractor reaped a good round profit. Since that time the well-point method has become standard in and around Chicago for all very wet or deep running sand ditches.

Clarence L. Kirk: Referring to Mr. Alvord's remarks, the speaker has used the well method in building sewers at depths of

18 to 24 feet and found very little difficulty with it. Points were used on both sides of the trench and a header was strung out 3 or 4 feet in length; a rather large pump, say a 10-inch size, was employed.

ACCOUNTING FOR INTEREST AND TAXES[1]

William W. Brush: In all but one of the boroughs of New York City the water revenues are paid into the General Fund and all expenses, including interest on and amortization of bonds, are paid out of that fund, which is raised mainly by taxation. Under a special law the water revenues are used for the maintenance of the water system in one of the boroughs. The New York method makes it impossible to determine readily what are the actual revenues and expenses of the water works. There can be no question but that the accounts should show every transaction which affects the water supply, on either the receipt or disbursement side. Further, every service rendered by the water works should be charged against some account on the books. The Bureau of Water is working toward this ideal and trying to obtain proper credits for water used in fighting fires, cleaning streets, supplying public buildings and other services rendered to other municipal departments.

Water works officials should devise a scheme whereby it can be readily shown what sums are paid for the maintenance and operation of a plant, interest charges and amortization of bonds, as well as the proper charges for parts of the works built by the proceeds of bond issues already retired. On the other side of the ledger should be shown the revenue that should be credited to the water works, including every item ordinarily considered a free service but which is a service for which a credit should be given. An item of estimated taxes against the works and all other proper charges should be entered in the cost of maintenance of the works. If all water works organizations keep such records and make a comparison with the accounts of other communities it will be possible for each official to find out if he is omitting some item and to learn what has been the real cost of supplying water and what would be the income of the plant if free service was eliminated.

R. B. Howell: Whether taxes are charged against a municipal plant is immaterial except in comparing the expenses of municipal

[1] Informal discussion at Richmond Convention, May 10, 1917.

and private operation under like conditions. If taxes are taken into consideration in a municipal plant the accounts should also show the sums set aside for the amortization of the plant's bonded indebtedness, which may be more than the taxes would amount to.

In Omaha the water works have been owned by a special district, now practically the same as the city, for about four and one-half years. In the year when the first bonds were voted to buy the plant, the taxes paid to the city by the Omaha Water Company amounted to about $14,000. Last year, out of the revenues of the plant, something over $137,000 was set aside to amortize the bonds. Two years ago the Nebraska legislature passed an act requiring the state authorities to audit the books of the Metropolitan Water District of Omaha, and in the audit there was charged against the earnings of the plant as possible taxes for 1916 something over $140,000, or about ten times what the water company had paid a few years before.

The Omaha Department is not allowed to charge the city anything for water for public use, but the city must contribute not less than 3 mills on one-fifth of the value of the water works property within the city, for fire-hydrant service. The income from this source is about $140,000, or between $50 and $60 per hydrant annually. An estimate of the amount the city ought to pay for water, based on formulas recommended by members of this Association, is about 40 per cent of the total revenue, whereas it is paying less than 20 per cent.

Unless city departments are charged for water just as individuals are charged, there will be great municipal waste of water. For instance a number of swimming pools are being built in Omaha and a demand is made to refill each pool daily. As some of the pools are very large, the quantity of water required for them will be great, and if the Park Department had to pay for this water it would soon devise some method of purifying it so that the supply could be used over and over, as is done elsewhere.

J. Walter Ackerman: The Water Department of Auburn, N. Y., is independent of other branches of the city government, except that it must pay taxes on the portion of its property outside the city limits. The Department charges the city the regular meter rates for water used in all public buildings and also charges a hydrant rental to cover the cost of fire protection. This rental is

probably too small, but it is at least an attempt at sound finance in this matter. The city charter, which is an old one, provided that the sum paid annually for hydrant rental must not exceed a certain total sum, which is the reason that this item in the Department's financial affairs leaves something to be desired. The Department pays all interest charges on its indebtedness and has a sinking fund for retiring all bonds as they become due; the sinking fund can be used for no other purpose, under the law.

Henry P. Bohmann: In Milwaukee no distinction is made between a municipal department and a private consumer. At the close of the year the city comptroller credits the Water Department with the sums charged to the other municipal departments for the water supplied to them. The hydrant rental is merely a nominal sum, $5 a year, and does not pay for the inspection, let along the maintenance. It was not fixed by the State Railroad Commission, which would probably allow at least $25 or $30 if the rate was submitted to it for determination. The amount collected from the city last year was $160,000, but the Department pays $200,000 annually into the general city fund, to be applied to the reduction of the general taxes and it pays the interest on its bonds and retires them when they become due.

George A. Main: In Daytona the annual charge for fire protection is not based entirely on the number of hydrants, but is $500 per mile of main plus $10 per hydrant. In this way the heavy investment expense for large pipes with few hydrants is equalized with the lower cost of smaller pipes having more hydrants. The city is charged a rental for Department property used by it and credited for services it renders, bonds it pays and a sum estimated to be the tax were the works owned by a private corporation. While the Department pays no taxes, the estimated taxes are charged against it in order that the affairs of the Department may be compared with those of privately owned works.

Frank A. Kimball: In New Jersey the same system of accounting is supposed to be followed by both public and private water works and other public utilities, but there are some municipal plants that have not yet been forced to comply with the law and regulations. The system of accounting provides for the entry of all

charges or credits for interest and other items, whether collected or not. Where a city department is charged for water, light or anything else, and the charge is not to be collected, the items are carried out in a "duplicate adjustment account." Thus all expenses and all income are shown by their proper accounts, whether actually collectable or not, and the true financial status of the utility as well as its status after the introduction of the duplicate adjustment account can be ascertained.

LEAKS FROM HIGH PRESSURE FIRE SERVICE MAINS[1]

By Henry B. Machen

For many years water works officials have discussed leakage from distribution systems and the effect of changes in pressure without being able to come to definite conclusions, due to the fact that, except that for single supply lines laid generally under most favorable conditions, after the main has been placed in service it has been impossible to separate leakage from consumption.

The high pressure fire system in the Borough of Manhattan, New York City, due to the fact that New York has not permitted any private connection to its fire mains, gives an opportunity to make tests on a distribution system of 128 miles of mains, 2728 hydrants and over 4748 valves covering an area of 3675 acres. The system has received during its ten years' life most trying tests. Each year it has had the pressure raised from say 35 pounds to from 125 to 250 pounds, an average of over two thousand times a year, due to fire alarms within the district, and for each period of twelve hours in duration during which no fire alarm has sounded the pressure has been raised for one-half hour to 200 pounds for testing out. It is hard to believe that any other water system in the world has gone through similar service conditions.

Table 1 gives in considerable detail the castings used, separated by contracts, by size of main and further sub-divided into full lengths of pipe of each size, offsets and bends of varying degree of curvature combined, 3-ways and 4-ways and short pieces. The short pieces were in many cases manufactured in the short lengths at the foundry; in other cases, they were cut from full lengths of pipe in the field. All castings used in the work except the pieces cut in the field were tested to 600 pounds at the foundry.

The 3-ways and the 4-ways were steel castings and considerable trouble was experienced at certain of the steel foundries in obtaining satisfactory castings. Two of the foundries, however, had practically no trouble in furnishing castings up to the specifications, the

[1] Read before the Richmond Convention, May 10, 1917.

troubles of the others being due to lack of experience in this class of work.

TABLE 1

Pipe and specials in the Manhattan high pressure fire system

ITEMS	TOTALS ALL CONTRACTS	PER CENT
8 inch full lengths	437	3.2
8 inch bends and offsets	3,257	24.1
8 inch 3-ways and 4-ways	297	2.2
8 inch short pieces	9,533	70.5
Total	13,524	100.0
12 inch full lengths	26,729	64.8
12 inch bends and offsets	4,937	12.0
12 inch 3-ways, 4-ways	2,045	4.9
12 inch short pieces	7,563	18.3
Total	41,274	100.0
16 inch full lengths	9,561	64.8
16 inch bends and offsets	1,515	10.3
16 inch 3-ways, 4-ways	894	6.0
16 inch short pieces	2,783	18.9
Total	14,753	100.0
20 inch full lengths	3,894	62.3
20 inch bends and offsets	703	11.3
20 inch 3-ways, 4-ways	417	6.7
20 inch short pieces	1,233	19.7
Total	6,247	100.0
24 inch full lengths	3,513	65.1
24 inch bends and offsets	422	7.8
24 inch 3-ways, 4-ways	626	11.6
24 inch short pieces	838	15.5
Total	5,399	100.0
All sizes:		
Full lengths	44,134	54.4
Bends and offsets	10,834	13.3
3-ways, 4-ways	4,279	5.3
Short pieces	21,950	27.0
Total	81,197	100.0

The mains were all laid in the lower portion of Manhattan Island, where subsurface conditions are most congested. This subsurface congestion shows readily in the figures given in the table by the large number of bends and short pieces of pipe used, even after the city had availed itself of its right to order moved gas mains and other interfering subsurface structures.

After the mains were laid they were subjected to an acceptance test of 450 pounds for a period of ten minutes for the earlier con-

TABLE 2

Lengths of pipe and leakage in the Manhattan high pressure fire system

ITEMS	CONTRACTS 6-7-8-9	CONTRACTS 19-20-21-22-23-27-28-29-30	TOTAL ALL CONTRACTS
24 inch pipe laid, linear feet	35,662.0	13,656.6	49,318.6
20 inch pipe laid, linear feet	29,849.8	26,330.0	56,179.8
16 inch pipe laid, linear feet	47,177.2	87,673.4	134,850.6
12 inch pipe laid, linear feet	154,466.1	224,429.0*	*378,895.1
8 inch pipe laid, linear feet	26,213.9	28,760.6	54,974.5
6 inch pipe laid, linear feet	860.0		860.0
Total pipe laid, linear feet	294,229.0	380,849.6	675,078.6
Linear feet of pipe joint	122,438	160,545	282,983
Allowable leakage for 24 hours	489,850	642,139	1,131,989
Actual leakage for 10 minutes	2,138.8		2,138.8
Actual leakage for 20 minutes		4,762.4	4,762.4
Actual leakage for 24 hours	307,741.	343,391	651,132
Total number of tests	647	720	1,367
Date put in service	July 1908 to November 1909	July 1910 to December 1914	July 1908 to December 1914

* Includes 150 feet of wrought iron pipe.

tracts and for twenty minutes for the later ones, the leakage being measured and for acceptance had to come within the limit of 4 gallons per linear foot of pipe joint per twenty-four hours. The results of these tests are shown in table 2, which gives, separated into the same contracts, the linear feet of pipe laid of each size, the total linear feet of pipe joint, the allowable leakage, based on the specifications of 4 gallons per linear foot of joint per twenty-four hours, the actual leakage for the test period and reduced to the twenty-four hour basis.

In testing, the test sections were in all cases between valves and doubtless a portion of the loss was due to water passing the valves limiting the section under test.

From the total column of table 2 it will be seen that the mains were limited in the acceptance test of 450 pounds per square inch to a leakage at the rate of about 800 gallons per minute for the entire 128 miles. The actual gross leakage of all the tests was 452 gallons per minute. Today there is a leakage, as shown on the Venturi meters, of 950 gallons per minute at an average pressure of 33 pounds, or nearly double the amount of leakage at 450 pounds pressure at the tests from ten to four years ago.

Investigations have been made to locate the leaks, but due to lack of force the work has not been systematically carried on. However, due to the wide range in pressures, property owners have themselves reported eight connections which had been placed evidently by mistake. There may be others not placed by mistake in which advantage is taken of the higher pressures available at times to fill tanks. The occasional erratic movement of the pen in the Venturi chart may be an indication of this.

The author had until recently a very firm belief that the leakage was past the main valve of the hydrants and was carried off to the sewer through the drain pipe connecting the drip and sewer. This belief has been shattered by an aquaphone test of each hydrant made by a most careful and competent inspector who covered every one of the 2728 hydrants and found but 51 (1.9 per cent) on which any sound could be detected indicating leakage which could not be stopped by tightening the valves.

Of course, it might be said that a certain number of hydrants might be not tightly closed at all times in such a large number, but the system of maintenance is such that each hydrant is examined and repaired if necessary immediately after going out of service at a fire by an experienced machinist who reports to a follow-up system that the hydrant has been examined by him and left in good condition. The firemen, after an alarm, are the only users of the hydrants. Should any one else open a hydrant it is immediately known by an alarm bell operated by the Venturi meter recorder on the priming line.

During the past six years many miles of streets have been opened for the construction of the rapid transit subways, exposing over 54,000 linear feet of the high-pressure mains. No leakage has been

found in the joints except an occasional sweat and from this evidence the Bureau of Water Supply is inclined to believe that the loss of water is not at the joints.

Fig. 1 gives the result of a test under varying pressure made on December 8, 1916. Attention is called to the almost straight line of the upper portion of the curve, which seems to indicate that the leakage is not from fixed openings, from which a leakage varying as the square of the pressure should be expected.

It may be that the symmetrical results obtained and shown on the curve are but accidental; that as the pressure increased the main valves of the hydrants, which close under pressure, closed more

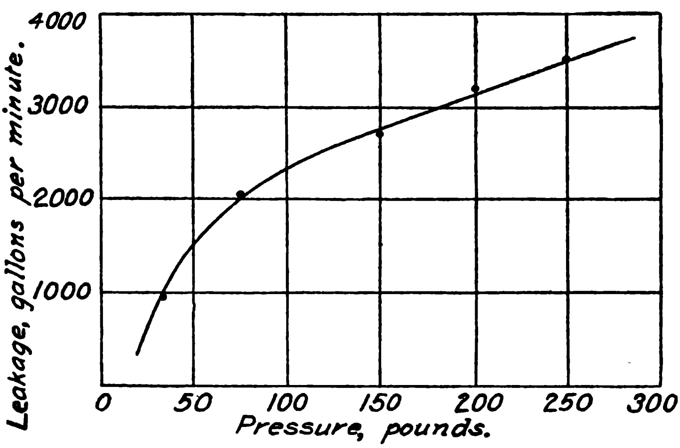

Fig 1.

tightly, reducing the leakage in the hydrant; that at the same time stuffing boxes in valves which are tight under low pressure might leak under the higher; that cracks in the pipe or steel casting not open under low pressure open under the higher.

Owing to a report of water coming in through the walls of a large sewer, there was located a split pipe which reduced the leakage under 35 pounds pressure by over 100 gallons a minute. This leak may have been of long duration, as at the time of starting excavations no indication existed at the street surface.

The author presents the above facts for the purpose of discussion and not as showing any definite conclusion as to leakage.

WATER SUPPLY STANDARDS AND THEIR IMPROVEMENT[1]

By William J. Orchard

Water supply standards may be divided into two classes:

1. Technical standards.
2. Non-technical standards.

Technical standards may again be divided into two classes:

1. Official standards, formed by the promulgation of laws and regulations.
2. Unofficial standards, which may be defined as those based on experience or current practice.

A résumé of legislation and the regulations of supervising health bodies indicates that the only definite technical standard that has been promulgated officially is that of the Secretary of Treasury, under date of October 21, 1914, being bacteriological standard of purity for drinking water supplied to the public by common carriers in interstate commerce.

From information available, it would appear that none of the State Health Departments has officially promulgated standards of purity, either bacteriologically or chemically. In many states, legislation exists prohibiting pollution of public water supplies or the sources from which they are obtained. A few of the State Health Departments recognize the standards of the Treasury Department and aim to have all water supplies conform to these limits. Other State Departments of Health have unofficial standards which are used as a means of guidance in interpretation of water analyses, most of these being bacteriological standards only.

Reports received from 31 State Health Departments indicate that 13 states have laws protecting water supplies, but have not adopted any minimum chemical or bacteriological standards. Two states have laws protecting water supplies and have unofficially adopted United Sates Treasury standards. Nine states have laws protect-

[1] Read before the Richmond Convention, Chemical and Bacteriological Section, May 10, 1917.

ing water supplies and have adopted tentative unofficial standards, while eight states have neither laws nor standards.

Unofficial or tentative standards that have been adopted by some of the State Departments of Health are of interest. A few examples are enumerated:

Minnesota. The Minnesota State Board of Health has not set any arbitrary standard for the purity of water. In interpretation of results, a water is not considered to be of good sanitary quality unless the bacteriological count for four days at 20°C. is less than 100 per cubic centimeter, and B. coli absent in 100 cc. samples. This standard is subject to qualification under certain conditions. The Minnesota State Board of Health will not report on any water supply unless a thorough field investigation has been undertaken and unless samples have been collected by its own representatives. This phase of the situation is presented in a paper by H. A. Whittaker, Director of the Division of Sanitation of the Minnesota State Board of Health, entitled "Fallacies in the investigation of Water Supplies," which was presented before the engineering section of the American Public Health Association in October last.

Alabama. The Alabama State Board of Health recognizes the standards adopted by the Treasury Department, allowing, however, a bacteriological count of 300 per cubic centimeter after twenty-four hours incubation at 37°C.

Virginia. The State Board of Health of Virginia has not adopted any standards and in an interpretation of analyses is largely governed by the particular conditions surrounding the source of supply, and even though a water derived from a protected watershed on which there is no habitation might show coli in 1 cc. and 10 cc. samples, unless human contamination could be shown, the water supply might be considered as good. For the information of local authorities, however, the Virginia State Board of Health indicates on its standard report forms, the significance of bacteriological counts and B. coli interpretations, differentiating between bad, suspicious or good supplies, as follows:

Where colon bacilli are found in quantities of 1 cc. of water, the sample is dangerous, and is reported bad, regardless of the number of other bacteria found in the sample.

Where colon bacilli are found in 10 cc. or 20 cc. of water, and the number of other bacteria is large, the sample is regarded as dangerous, and is reported bad.

Where colon bacilli are found in 10 cc. or 20 cc. of water, and the number of other bacteria is small (less than 500 per cubic centimeter) the specimen is classed as suspicious.

Where colon bacilli are not found in samples; and, where bacteria are less than 500 per cubic centimeter, the sample is reported good.

Maryland. The State Department of Health of Maryland has not established any standards or limits on the quality of public water supplies, but certain standards have been recommended for filtration plants. These standards are quite novel and are based on a coefficient of efficiency, which is defined as "the ratio of the logarithm of raw water count at 20°C. to the logarithm of the plant effluent count." For the removal of colon, the standards are based on a so-called "standard hygienic efficiency," which is defined as "the sum of the percentages obtained by allowing a value of 20 per cent to each successive step in the colon removal." These standards are discussed in detail in a paper by Wolman, published in the *American Journal of Public Health*, November, 1916.

Montana. The Montana Department of Health has adopted tentative chemical standards for the hygienic purity of waters, applicable to restricted areas in the state, and, as a rule, only supplies that show no B. coli in 10 cc. are recommended for public consumption.

California. The California Bureau of Sanitary Engineering considers a supply in which B. coli can not be confirmed in 10 cc., by the latest laboratory methods, as being safe. The occasional occurrence of B. coli in the same quantity is not considered seriously, but their presence in 10 cc. continuously, or in less than that amount occasionally, is not considered favorably. Condemnation is usually reserved for a field inspection to determine if possible what portion of the B. coli are of human origin.

Iowa. Iowa presents the interesting situation where chemical standards adopted for the waters of the state several years ago have been abandoned, following the collection of information showing their inadequacy.

A résumé of reports received from over 30 State Health Departments shows the varied interpretations placed on bacteriological analyses, and the relative importance given to sanitary survey of watersheds in conjunction with analyses.

If the standards of the United States Treasury Department must apply to all water supplies used in interstate traffic, and, if as experi-

ence has clearly shown, supplies used by railroads can conform to Treasury standards, the interesting contention is presented that all public water supplies should conform at least to this standard.

If all supplies do not measure up to this standard, the regulation works an injustice on a few supplies, and does not accomplish a general improvement in the water supplies of the country, as might otherwise be the case.

If there are two towns, located one on either side of the state boundary, designated as A and B, A being a watering place for railroad equipment and B being a way-station, according to existing legislation, the supply of A must conform to the Treasury standard, and the supply of B can be anything that the state and local officials will permit. To make the water supply of A conform to the standards has, in all probability, placed a burden either on the water company or the tax payers of the municipality, and has correspondingly improved the welfare of the town. Is it equitable to require A to go to this expense and not to impose a similar obligation on B? On the other hand, in justice to the consumers at B, should they not be afforded the same protection as those at A?

It is appreciated that in suggesting the feasibility of adopting tentative minimum bacteriological standards, the principal objection to such procedure is the inability properly to consider the sanitary surroundings of the source of the water.

The abundant good that has been accomplished on a relatively few supplies, following the establishment of Treasury standards, however, would indicate that a considerably greater number of supplies could be improved, should minimum standards be promulgated for all of them.

Whether or not we are governed by arbitrary or tentative standards, more or less definitely fixed, those who in the course of their work are called upon to interpret large numbers of bacteriological analyses, unquestionably are governed by standards that they have set, upon which the interpretation is based, and this interpretation is made, first, without reference to a sanitary survey; and, second, in conjunction with a sanitary survey to determine, if possible, the sources of any apparent pollution. But these personally established water standards vary with the indvidual's interpretation of the analyses.

A water showing coli in 0.1 cc. regularly will unquestionably be

condemned, as will also, without doubt, a supply usually showing coli in 1 cc.

A water showing coli frequently in 5 cc., and occasionally in 1 cc., will very likely be rejected by most sanitarians, although the frequency with which such supplies are furnished to consumers, without rigorous steps being taken to improve the quality, is surprising.

When we reach a water, however, with coli present frequently in 10 cc. quantities, and occasionally in smaller amounts, the interpretation of the analysis lies very largely with the individual, and the supply may be rejected or passed in accordance with the individual's standards.

Although the difficulties of arbitrarily establishing any minimum bacteriologcal standard are appreciated fully, it would tend greatly to improve the quality of a great number of supplies, if minimum standards, adopted after careful investigation, were to be officially promulgated by this Association. Should such standards be available for water companies, commissioners and consumers, a definite object would be established, and the best results in any line of endeavor are secured only when a definite objective is in view. On the other hand, should such minimum standards be established, being intelligently drawn and formed only after due consideration of geographical conditions, they would unquestionably aid the supervising health officials in dealing with the recalcitrant water vendor, for the state sanitary engineer would have a definite objective that he could order the vendor to reach.

Although the United States Treasury standards are high as compared with many water supplies in this country, and although a large number of waters of our bigger and better known cities will not at all times conform to the Treasury standards, they are not high as compared with the standards existing in European countries and Great Britain.

It was expected that a considerable fund of authenticated information would be available to incorporate in this paper to cover standards prevailing in these countries, and the limits of bacteriological content that are considered good practice. Presumably, this information has been lost in transit and will have to be incorporated subsequently. Many English water works men, however, contend that the total bacteriological content after twenty-four hours incubation at 37°C. should not be more than 50 per cubic-centimeter, and that colon should be absent in 100 cc. quantitites

after seventy-two hours incubation at 37°C. and some even go as far as to aim to have colon absent in 200 cc. after seventy-two hours incubation at 37°C. An examination of the Twelfth Research Report of the Metropolitan Water Board, of London, would indicate that the settled, stored and treated waters of various supplies before filtration were comparable bacteriologically with some of our American water supplies as delivered to the consumer.

In advocating the adoption of minimum bacteriological standards of water, the object in view would be to improve the poorer supplies and to establish a guide by which a non-technical water-works man could appraise his supply, to establish standards not so much as an arbitrary means of appraisal as an incentive to secure better water supplies. It is therefore suggested that consideration be given to the appointment of a sub-committee to determine the practicability of adopting standards similar to the United States Treasury standards for all water works, whether they be used for inter-state traffic, or not.

NON-TECHNICAL STANDARDS

Technical standards are easily explained in scientific terms intelligible to those familiar with their use. Non-technical standards are more difficult to explain but may be defined as the attitude of the non-technical man toward a water used for domestic purposes. These may well be divided into two classes:

1. The standards of the non-technical water works man.
2. The standards of the consumer.

It must be realized that there is a large number of water works men in this country, not members of this Association, who do not know to any extent the necessity of a pure water supply, and to whom the colon bacillus and bacterial flora in general are unknown. Fortunately, the number of water works in charge of this type of man is fast diminishing. The only reason that so many non-technical water works men are entirely unfamiliar with the need of safe water, and the care and vigilance that must be used to secure a safe supply, is that they do not know the fundamental reasons for a safe supply. Two instances are worthy of mention:

A certain surface water supply in New England, upon investigation following a typhoid epidemic, was almost definitely found to have been polluted by a typhoid-carrier hunter. The State Board of Health representative, sent to install a temporary treatment

plant, was ordered out of the pumping station by the water commissioners who waited on him in a body, to inform the Board of Health man that they were running that water works; that the water supply suited them; and, State Board of Health or no State Board of Health, he could not install the treatment plant, and the only thing he could do was to get out, which, having no authority under the law, he did.

The second instance is that of a water works superintendent of a small municipality which was required by the State Health Department to install a treatment plant. Upon the arrival of the representative of the company furnishing the purification apparatus, the superintendent roundly abused the State Board of Health officials, ridiculed the necessity for treatment, in spite of the prevailing epidemic, and informed the representative that he was not going to permit the State Board of Health to install any more contraptions that would mean more work for him; and that although he would treat the water while the State Board of Health man was around, he would pay absolutely no attention to the equipment at other times. Subsequent experience has indicated only too well that he carried out this threat.

Such attitudes on the part of non-technical water works men are only too familiar to those whose work has as its foundation the improvement of water supplies in general, and it can be combated only by a most aggressive educational campaign, which properly should be supervised by this Association.

Contrast with this attitude that of the progressive private water company or the water department conducted by a technical man, or by individuals who realize the vital importance of their work. The large progressive water companies or departments take every possible means at all times to improve their water supplies; to raise the standards by which they are appraised and by which the consumers are influenced. Such water companies, by taking the consumers frankly into their confidence, place themselves on such a firm foundation as to be able to withstand whatever adverse criticism may be directed against them.

The experience of the Indianapolis Water Company, of Indianapolis, Ind., which has taken its patrons into its confidence in regard to the treatment of its water supply and has established a reputation in Indiana of furnishing absolutely safe water under all conditions, is worthy of note. This confidence has carried the water

company without criticism through two severe epidemics and has been invaluable in the matter of dollars and cents as well as good will. A similar attitude on the part of other water companies has had a comparable result. Is it not incumbent upon this organization to endeavor to create a similar attitude on the part of every water vendor?

The water standard set by the consumer is for the most part one of appearance. If a water is not turbid or colored, he is usually satisfied. Unless his immediate family has been vitally touched by the effects of an impure water supply, he is not solicitious about the quality of the supply. This matter was discussed at length by Johnson in his paper, "The Typhoid Toll," presented before this Association, and was amplified in the printed discussion of that paper.

The consumer is, however, inextricably connected with the establishment of higher standards for a water supply. To obtain better water supplies, money is needed and a considerable quantity of it. A water company cannot improve its supply without incurring expense, which should bring return in the shape of increased rates, and increased rates can only be obtained with the partial consent, at least, of the consumer. Similarly, municipal supplies, if improved, increase the tax rate, and here again the consumer is the court of last resort.

The complacent and erroneous impressions that many water consumers have in reference to their supplies must be eliminated by careful, painstaking publicity and education. In discussing water supplies of various communities with non-technical men and water consumers, one is frequently advised that the water supply is the purest in the country; that it is 99.9 per cent pure; or, that it is well water that never sees the light of day and is absolutely safe. The individual cannot be blamed for resting secure in these assertions, for he does not know better.

Most of those present at this meeting, in going into a strange city or town, do not drink the water furnished until the nature of the supply has been ascertained. Many of us abstain from drinking water when on road trips, even in territories where other liquid refreshments are not easily obtained, simply because we appreciate the pollution that a water may carry and the danger that may lurk in a tumblerful. The average consumer, however, seldom gives this matter a thought, because his training has not taught him to do so.

Should this Association be instrumental in making the water consumer stop before he draws a tumblerful of water from the spigot and inquire as to the purity of that supply before he drinks the water, it would have a tremendous effect on the improvement of water supplies.

A more complete and masterful presentation of the value of pure water than that contained in Johnson's paper, "The TyphoidToll," was probably never presented before any Association. In it, the author says that more people are killed every year by typhoid fever than by railroads. The water consumer will stop and look before he crosses a railroad track, we must make him stop and think before he drinks a glass of water. Mr. Johnson has shown that a pure water supply is a good dollars and cents business proposition; why not treat it as such? Why not pattern our conduct as a water works association after that of a successful business organization? Are we not at all of us, water works superintendents, engineers, chemists, bacteriologists, manufacturers, or what not, offering our services and our product, water, to our final customer, the consumer? Being honorable men, we want to give him the best that he will pay for, and he will only pay for the best when he is educated to its need. With the consumer educated and demanding the best in water supplies, there will be no further danger from the non-technical, disinterested, or slovenly water works vendor, for he will not be permitted to do business.

Looking at this matter, then, as a business proposition, seeking to find a market for a water supply of higher standards than most of those at present furnished, should it not be approached in the same manner as any successful business campaign? Given a good product for which there is a market, the success of any business depends on bringing the product to the attention of those using it, and that can only be done by advertising and publicity. Why not have this Association act as an advertising or publicity medium to obtain higher standards on the part of the technical and non-technical water works man and also the consumer? Begin with the consumer; advertise to him the value of better water so that he will demand the best, and be willing to pay for it. Then, he will get it.

The efforts toward improvement made by vendors of water used in interstate commerce, which could not be certified under Treasury ruling, are significant of what can be done under compulsion. How much more could be accomplished if the consumer was the compelling

force all over the country? We are all familiar with the progress made in campaigns to secure better housing, better factory conditions, better environment for employees, and protection from occupational diseases? We are also familiar with the tremendous strides in the anti-tuberculosis campaign, and the many exhibits used to educate the public along these lines. Many State Health Departments have traveling exhibits in charge of medical or technical men, which tour their states to give the public visible evidences of the results obtained from money they have expended.

Are we not lacking in the fulfillment of the highest objective of this Association unless we endeavor by every means at our disposal to educate the general public as to the value of pure water? Are we not stulifying the influence of Johnson's paper if we confine it, for the most part, to the technical water works man? Should we not see to it that its contents are advertised broadcast as a good business proposition?

Let us suppose that graphic illustrations of the value of pure water were to be incorporated in every public health exhibit in the country; were to be made part of traveling exhibitions; to be incorporated by the Boards of Education in instructions given in school rooms, and disseminated by every educational medium. It would not be long before the demand for better water would be so insistent as to cover the entire country.

And, with the objective of creating this demand on the part of the consumer, and thus offsetting the deleterious influence of the careless water vendor (and to support the technical water works man in the promulgation of higher standards of water supplies) this suggestion is offered: that this Association appoint a committee to consider the feasibility of a joint board to consist of four members, one each appointed by the Presidents of the American Water Works Association, the New England Water Works Association, the American Public Health Association, and the Water Works Manufacturers Association, these four men to appoint a publicity or press agent, who might well be one of the Secretaries or Editors of those Associations, whose sole duty would be to spread the propaganda of better water supplies. There are many problems presented; the cost of broadcast publicity at first would be prohibitive, but intensive advertising campaigns could easily be conducted in certain localities.

Sub-committees could be appointed to confer with various State

Departments of Health, covering publicity in their territory. Other sub-committees could be appointed in some states, if necessary, to endeavor to secure legislative enactment to protect water supplies, and create an interest in the subject. Arrangements could be make with some of the larger private water companies to advertise steps they have taken to protect their supplies along the lines previously mentioned as having been undertaken by the Indianapolis Water Company. Other sub-committees could make arrangements with the boards of education, libraries, and exhibits.

This is a tremendous undertaking, but unquestionably it is worth while. It is a campaign which would take years to properly cover the country, and it is not to be expected that the tangible results would be immediate. That the end to be accomplished is a good one is beyond dispute, and in aiding to spread the gospel of pure water, this Association will fulfill its highest function.

DISCUSSION

F. W. Green: At Little Falls, N. J., the water has an average bacteriological content of 2 bacteria per cubic centimeter and at the same time a B. coli index of 0.03; this means about 3 B. coli per 100 cc. The company considers the water not only the best in its section but one of the best in the country. In Paterson, a city of 125,000 population, the typhoid rate is 9 per 100,000, which is about the lowest in the country for a city of its size, and practically the same rate obtains in the other municipalities served.

It is not possible to make a standard that will cover all cases. There are many places where water is filtered and the supply undoubtedly contains B. coli, yet that supply is perfectly safe. There are a number of large cities where the supply, taken from surface streams, is such that it is difficult to determine the exact amount of sterilization necessary to eliminate the coli. To remove the last innocent B. coli, which is not a sign of harmful pollution but only indicative of a possible danger, it is necessary to dose in more chemicals to increase the sterilization, and that causes complaint of tastes and odors besides incurring more expense.

Chester G. Wigley: The paper brings out a point, quite clear to any one supervising different water supplies, that the standards used by different departments vary very considerably. This is

possibly because the bacteriology of water supplies has not yet reached an absolutely definite position. The tendencies are toward refinements of the present procedures, and until those refinements have been worked out it is a rather difficult proposition to establish any definite standards. The standards of the Public Health Service have been of considerable value to those in charge of the water supplies of cities and states on account of their influence toward the betterment of supplies.

The subject of railway water supplies is probably in a somewhat different category from that of the municipalities. A railway picks up its supply at some point along its line, and it is often not a very severe task for it to substitute an unquestioned source of supply for one under suspicion. On the other hand, a municipality is frequently tied up with very heavy investments on its water shed, over which the most careful control must be maintained at all times to supply a water that is in any degree safe.

It is a question whether at present it is prudent to establish any standards except those which experience has shown to be absolutely necessary. In the last analysis the health of a community using a certain water supply is practically the only absolute measure of the quality of that water. In time a more definite standard will be worked out, but attention is called here to a point made by Professor Jordan, of the University of Michigan, in a paper on the bacteriological standards for food products, published in the *Journal of the American Medical Association*. This point is the danger of establishing standards for food products beyond those which it is absolutely certain are indicative of the quality of those products, his opinion being that to establish standards beyond those which bacteriology had demonstrated were absolutely necessary for safety might in the end lead to a repetition of the experience of the Royal Commission on Sewage Disposal of England. That commission, establishing standards ahead of the development of the science, was under the necessity later of amending in some way those early standards, the result being that the portion of the public affected naturally lost a certain amount of confidence in the technical ability of those responsible for the adoption of the standards.

The author has advanced one very important matter for consideration, the subject of publicity. It is a well accepted fact now that the greatest force that can be used in any public health work is publicity, and that matter should have the earnest consideration of

this Section. It is a large subject which has not yet been given much thought.

EDWARD BARTOW: The suggestion just made regarding publicity recalls a notice that was printed for years on the menu cards of a Champaign hotel: "This water has been analyzed by the chemists of the University of Illinois and found to be absolutely pure." The University has made no analysis of the water used in that hotel, unless it was a very long time ago and an ancient analysis been advertised for years and years.

The paper suggests a joint committee representing four societies to consider the advisability of combined action in matters relating to standards of water supply. The paper mentions the American Chemical Society as particularly interested in chemical analytical methods and standards, the Society of American Bacteriologists and the American Public Health Association as interested in bacterial standards, and the American Water Works Association as interested in teaching the public about the value of good water. It might be well to add the American Railway Association, which has already established standards for locomotive water supplies. The chemical standard of water is very important to railways and many industries.

JOSEPH RACE: One of the most important points raised by the author is the United States Treasury or Public Health Service standard. It ought to be seriously considered by this Section because, on account of its application to interstate carriers, it practically sets a minimum standard for the whole country. It also seems inevitable that, in the absence of opposition, it will become the standard for the contiguous territories of Canada and Mexico. In Canada, the question of standards has already arisen in connection with international water carriers. The Washington authorities made regulations some months ago and attempted to put them into effect at the opening of the present season of navigation. At the request of the Canadian authorities the proposed regulations were suspended for twelve months so that the two countries could consider and adopt regulations that would not conflict.

Two points ought to be considered in connection with this standard. First, what method is to be used for the determination of B. coli? If the method is to be that of the American Public Health Association, which apparently changes everv time the Association's

committee makes a report, the result will be chaos to water works. Water works managers ought to take more interest in the standard methods of analysis and insist upon less frequent changes. Second, what is the minimum time that may be permitted between the collection of the samples and their examination? In supplies like reservoir and filtered waters the bacterial conditions may have reached an equilibrium and but little change will then occur during a further period of storage. In waters that have been treated with chlorine the case may be quite different and the B. coli content may be very much less after twelve hours. It is very desirable to adopt a standard method of procedure.

L. I. Birdsall: In regard to the publicity side of water works affairs, conditions in Minneapolis may be mentioned. The Department has been laboring for the last four and a half years, ever since the filtration plant was established, to convince the people that they are being supplied with pure water. The spring water people have persistently said all manner of mean things about the municipal water supply, which is taken from the Mississippi River. In its campaign of publicity the Department started out with an official guide at the filtration plant and since then on an average 10,000 persons have visited it annually. Then pamphlets were issued explaining the whole system, how the water is purified, how it is proved to be pure, and giving some of the results of tests of its quality. These pamphlets are sent out with the water bills and one reaches every consumer. Another means of publicity is the use of stereoptican slides. A number of organizations in the city ask the department heads to talk to them about water, which is done gladly with the help of these lantern slides. One of them shows a reduction in the typhoid fever cases in Minneapolis from 58 per 100,000 in 1910 to 4.7 in 1916. The results in this publicity work are becoming apparent and the people of the city are coming to realize that they are obtaining pure water.

CHLORINATION AND CHLORAMINE[1]

By Joseph Race

The studies reported in this paper are a continuation of those recorded in last year's Journal (vol. 3, 1916, 439–449) and constitute a partial attempt to place water chlorination on a scientific basis. Until comparatively recently the data that we possessed were a disconnected mass of empirically established facts, and it is a regrettable feature that although it is on this continent that the *art* of chlorination has progressed the most rapidly, it is in Europe, under the stimulus of war, that it is being developed as a *science*. As chlorination becomes more general it becomes increasingly evident that our stock of information regarding the conditions that tend to successful results is very meagre, and that the dosage is largely determined by the trial and error method. We are also lamentably ignorant as to the reason why some waters have but very small margins between the dose required for satisfactory purification and that which causes complaints as to tastes and odors, while others have much greater ones and can easily absorb slight excesses of the sterilizing agent. Complaints that arise in this way are often ascribed to auto-suggestion by water works and health officials, but they are too often based upon solid fact to be disposed of in this manner, and the time and energy that have been devoted to deluding the public might much better have been spent in improving present methods and so eliminating the cause for complaints. Chlorination is such a cheap and simple process that it is often considered the *ultima thule* of chemical sterilization, but there is no reason to doubt that the present methods will be modified and considerably improved. A simple modification that has yielded good results with some waters will be described later, but before treating that in detail a few general factors will be considered. In the last paper, the author gave results showing the effect of time, mechanical admixture, temperature, and organic matter upon chlorination by

[1] Read before the Chemical and Bacteriological Section of the Richmond Convention, May 10, 1917.

bleach and also the relative viability of various types of B. coli to chlorine. In the present paper the effect of acids, alkalies, and salts will be discussed and a new explanation given of the *modus operandi* of chlorination.

All the experiments described below were made with the raw Ottawa river water, the general characteristics of which are as follows.

	parts per million
Free ammonia	0.005–0.015
Albuminoid ammonia	0.088–0.110
Chlorine	1.5 –2.5
Nitrites	Traces
Nitrates	0.045–0.080
Oxygen absorbed in 30 minutes at 100°C.	9.0 –11.0
Alkalinity	25.0 –35.0
Free carbonic acid	0.66 – 1.32

Approximately 10 parts per million of calcium and magnesium sulphates and 0.5 parts per million of iron are usually present in addition to the bicarbonates and chlorides. The turbidity and color are recorded separately for each experiment.

The bacteriological experiments were made by adding the various chemicals to the water, contained in glass bottles, after seeding with a pure culture of B. coli and plating out 10 cc. after the contact indicated in the tables; 40 cc. rebipelagar (neutral red lactose bile salt agar) were added to the water and the plates incubated for twenty-four hours at 37°C.; the characteristic red colonies produced by B. coli were then counted and recorded. The results obtained are recorded in table 1.

Chlorides. The effect of small quantities of sodium chloride (up to 10 parts per million) is apparently very limited, but larger amounts tend to increase the velocity of the germicidal action of the hypochlorite. Sodium chloride itself has no effect on the viability of B. coli during the period covered, viz., five hours (experiments 1, 2, and 3).

Caustic potash. In quantities up to approximately 5 parts per million caustic potash has but little effect. At 5 to 10 parts per million the velocity of the germicidal action is materially reduced but when higher amounts are present the germicidal action of the alkali itself begins to take effect and may entirely nullify the retarding effect on the hypochlorite (experiments 4, 5, and 6).

TABLE 1

Effect of different quantities of several chemicals on the bacterial content of raw Ottawa River water. Results are B. coli per 10 cc.

EXPERIMENT NO.	AVAILABLE CHLORINE	ADDED CHEMICAL	PHYSICAL CONDITIONS		CONTACT PERIOD										
			Color	Turbidity	Nil	10 mins.	30 mins.	1 hour	1½ hours	2 hours	3½ hours	4 hours	5 hours	6 hours	24 hours
	p. p. m.	p. p. m.													
		Sodium chloride													
		Nil	40	4	143			97		35	3		0		
1	0.40	1.0						97		37	6		0		
		10.0						88		35	7		1		
		90.0						75		17	2		0		
		Sodium chloride													
		1.0	40	10	133			94		46	15		4		
2	0.40	5.0						103		37	13		3		
		10.0						92		43	12		5		
		20.0						88		39	6		0		
		Sodium chloride													
		Nil	40	60	214			209		205	206		202		
3	Chlorine absent	10.0						208		198	204		200		
		50.0						201		203	206		214		
		90.0						208		204	208		216		
		Caustic potash													
		Nil	40	4	258	155		131				0		0	0
4	0.40	0.74				160		118				0		0	0
		7.4				150		118				60		46	0
		37.0				158		48				0		0	0
		Caustic potash													
		0.74	40	4	185			75		40		0			
5	0.40	3.7						112		90		0			
		7.4						85		64		63			
		18.5						80		43		44			
		Caustic potash													
		Nil	40	4	146			150				160		145	95
6	Chlorine absent	7.4						126				140		128	87
		37.0						129				130		121	34
		74.0						131				124		90	0

TABLE 1—*Continued*

EXPERIMENT NO.	AVAILABLE CHLORINE	ADDED CHEMICAL	PHYSICAL CONDITIONS		CONTACT PERIOD										
			Color	Turbidity	Nil	10 mins.	30 mins.	1 hour	1½ hours	2 hours	3½ hours	4 hours	5 hours	6 hours	24 hours
	p. p. m.	*p. p. m.*													
7	0.40	Sulphuric acid													
		Nil	40	4	80			51		25	7		3		
		1.6						45		20	4		0		
		6.5						35		15	1		0		
		16.3						17		3	0		0		
8	Chlorine absent	Sulphuric acid													
		Nil	40	50	285			282		287	285		282		
		6.5						280		282	262		240		
		16.2						285		285	255		220		
		32.5						290		275	222		190		
9		Carbonic acid													
	0.35	Nil	40	4	197	205	141	87							0
	0.35	Saturated				90	70	50							0
10	0.35	Sodium carbonate													
		Nil	30	15	70		44	40	37				2		
		5.0					45	38	36				1		
		25.0					52	42	38				11		
		90.0					56	44	38				9		
11	0.35	Sodium bicarbonate													
		Nil	38	9	140		85	82	73			63			
		5.0					93	75	68			60			
		25.0					90	80	65			60			
		90.0					93	73	35			28			
12	0.35	Effect of light													
		In bright sunlight	38	9	215		130	122	61		0				
		In dark cupboard					145	136	130		32				

Acids. The bleach solution used in experiment 9 contained 0.01 per cent of available chlorine and was dissociated to the extent of 40 per cent. This was carbonated until hypochlorite was more than 95 per cent dissociated.

The results of experiments 7, 8, and 9 show that small amounts of acid, whether added as a strong mineral acid, or a weak acid such as carbonic acid, increase the velocity of the action in a marked manner. Sulphuric acid alone has a germicidal effect but insufficient to account for the observed effect of the addition of acid to hypochlorites.

COMPARISON OF VARIOUS SOURCES OF CHLORINE[2]

1. Bleach and chlorine gas. The results in experiment 13 show a slight difference in favor of the solution of chlorine gas, but it is so small as to be of no practical importance. A similar conclusion is reached by Avery (*Report of the Ontario Provincial Board of Health, 1914*) after a number of experiments with sewage-infected water. The general characteristics of the water used by Avery are very different to those of the Ottawa supply; the Toronto supply is much harder (alkalinity about 100) and contains no color. The results obtained in Ottawa and Hull are perhaps of more value than laboratory experiments. Both these cities take their supplies from the same river and from approximately the same location, and daily analyses extending over a period of years have proved that the raw water is the same in both cases. In Ottawa the water was treated with straight bleach and in Hull with liquid chlorine from a modern type of apparatus, both using the same dosage. When tap samples from the two cities were examined after the same contact period the results were practically identical. For a short period liquid chlorine was used in Ottawa and the results were very similar to those obtained with the same dosage of chlorine as bleach.

2. Bleach and electrolyzed salt. In experiment 14 there is a slight difference in favor of the electrolytic product but insufficient to be of practical significance. The electrolyzed salt solution was obtained from a large-sized Dayton cell and contained 13 pounds of salt per pound of available chlorine.

3. Bleach and ammonium hypochlorite. The ammonium hypochlorite used in experiment 15 was prepared by double decomposition of a solution of bleach by ammonium oxalate and removal of the calcium oxalate by centrifugalization. No excess of oxalate was present.

The abnormally high efficiency obtained with what was presuma-

[2] See table 2.

TABLE 2

Comparison of various sources of chlorine. Results are B. coli per 10 cc.

Experiment no.	Available chlorine	Source of chlorine	Ammonia	Physical conditions: Color	Physical conditions: Turbidity	Contact period: Nil	10 mins.	30 mins.	45 mins.	1 hour	1¼ hours	1½ hours	2 hours	3½ hours	4 hours	24 hours	48 hours
	p.p.m.		p.p.m.														
	0.4	Liquid chlorine		40	4	195	160			60					36	20	6
	0.4	Bleach					170			75					51	30	17
13	0.5	Liquid chlorine					150			26					1	0	0
	0.5	Bleach					160			30					1	0	0
	0.4	Bleach		40	4	182		130		66			3	0			
14	0.4	Electrolyzed salt						115		60			1	0			
	0.6	Bleach						30		1			0	0			
	0.6	Electrolyzed salt						25		0			0	0			
	0.3	Bleach		40	4	440	380			320					180	26	1
15	0.3	Ammonium hypochlorite				280	80			4					0	0	0
	0.4	Bleach				440	300			218					112	6	1
	0.4	Ammonium hypochlorite				280	30			0					0	0	0
	0.5	Bleach				440	290			191					59	2	0
	0.5	Ammonium hypochlorite				280	10			0					0	0	0
	0.35	Electrolytic hypochlorite	Nil	25	45	58		31		27		20		1			
16	0.10	Electrolytic hypochlorite	0.05					41		19		7		0			
	0.20	Electrolytic hypochlorite	0.10					26		0		0		0			
	0.35	Electrolytic hypochlorite	0.15					0		0		0		0			
	Nil	Bleach	Nil	40	6	365	370			360					380	330	260
	0.4	Bleach	Nil				240			118					9	8	4
17	0.6	Bleach	Nil				160			44					1	0	0
	0.2	Bleach	0.10				280			24					2	0	0
	0.3	Bleach	0.15				210			7					0	0	0
	0.4	Bleach	0.20				115			3					0	0	0
	0.2	Bleach	Nil	41	5	145	133			113					110	110	
	0.5	Bleach	Nil				114			24					7	0	
18	0.2	Bleach	0.05				72			7					3	0	
	0.2	Bleach	0.10				76			4					0	0	
	0.2	Bleach	0.20				81			6					1	0	

TABLE 2—*Continued*

EXPERIMENT NO.	AVAILABLE CHLORINE	SOURCE OF CHLORINE	AMMONIA	PHYSICAL CONDITIONS		CONTACT PERIOD											
				Color	Turbidity	Nil	10 mins.	30 mins.	45 mins.	1 hour	1¼ hours	1½ hours	2 hours	3½ hours	4 hours	24 hours	48 hours
	p.p.m.		p.p.m.														
19	0.2	Bleach	Nil	40	8	173			165		155		140		130		
	0.2		0.025						150		120		4		0		
	0.2		0.050						140		112		4		0		
	0.2		0.100						135		105		3		0		
20	Nil		0.17	40	8	215				212					218		
	Nil		0.35							215					212		
	Nil		5.00							210					205		
21	0.20	Liquid chlorine	Nil	40	5	130	135			130					120	120	
	0.20		0.05				140			130					112	145	
	0.20		0.10				130			128					110	160	
	0.20		0.20				135			120					105	170	

bly ammonium hypochlorite was subsequently confirmed on several occasions. If the velocity of the germicidal action is calculated on the results obtained with 0.3 part per million of available chlorine the following values are obtained by means of the formula

$$v = \frac{\log \dfrac{N_1}{N_2}}{t_2 - t_1}, \text{ when } t_1 = 0.$$

t_2	VELOCITY COEFFICIENT OF		RATIO $\frac{\text{AMMONIUM SALT}}{\text{CALCIUM SALT}}$
	Calcium salt	Ammonium salt	
hours			
1	0.138	1.841	13.3
4	0.099	+0.612	+6.2

These figures indicate very clearly the marked increase in the velocity shown by the ammonium salt. From a consideration of the chemical formula of ammonium hypochlorite it appeared proba-

ble that it would be exceedingly unstable and decompose into chloramine and water according to the equation: $NH_4OCl = NH_2Cl + H_2O$. Chloramine has previously been found to have a carbolic coefficient of 6.6 as compared with 2.2 for chlorine. (S. Rideal, *Jour. Roy. San. Inst.*, 1910, 31, 33–45.) A dilute solution of pure chloramine can be prepared by Raschig's method (*Chem. Zeit.*, 1907, 31, 926) in which dilute solutions of bleach and ammonia are mixed in such proportions that the anhydrous ammonia is equivalent to the available chlorine (approximately two parts by weight of chlorine to one part by weight of ammonia). During the addition of the ammonia the solution of bleach should be surrounded by a freezing mixture and the mixture kept as cool as possible until the evolution of gas has ceased. The solution is then saturated with zinc chloride and magma distilled under reduced pressure. The distillate is a dilute solution of pure chloramine. Rideal (loc. cit.) found that mixtures of electrolytic hyphochlorite and ammonia produce chloramine and this is confirmed by the results given in experiment 16. The effect of adding ammonia to bleach solutions is shown in experiment 17. If the results are calculated by means of the formula given on page 69, the following velocity coefficients are obtained, t being expressed in hours.

$t_2 - t_1$	STRAIGHT BLEACH		BLEACH PLUS AMMONIA,		
	Available chlorine parts per million				
	0.40	0.60	0.20	0.30	0.40
0.166 (10 minutes)	1.092	2.149	0.691	1.440	3.369
1.0 (1 hour)	0.490	0.919	1.182	1.747	2.085

Over a period of one hour the velocity coefficient of 0.20 part per million of chlorine plus an equivalent of ammonia is greater than that of 0.60 part per million of chlorine without ammonia.

The next step was to determine the most efficient ratio of chlorine to ammonia. The results are given in experiments 18 and 19. Experiment 18 shows that there is apparently but little difference in the results when the ammonia is present in amounts that lie between one half the equivalent of the chlorine and double the equivalent. The tendency of amounts larger than the equivalent is an adverse one, due, possibly, to the production of hydrazine or ammonium chloride. Experiment 19 shows that when the ammonia is as low

as one quarter the equivalent of the chlorine, the velocity of the reaction is practically as great as when an equivalent is used. No satisfactory explanation of this can be advanced at present by the author, but in corroboration of the results the figures in table 3 are given, which show the rate of absorption of available chlorine for various ratios of chlorine and ammonia.

Similar indications were given by testing the bleaching power of solutions containing various ratios of chlorine to ammonia. All the laboratory experiments that have been made, indicate that the effect of the ammonia is altogether out of proportion to its amount.

TABLE 3

Rate of absorption of chlorine

10 parts per million of available chlorine added. Temperature, 65°F.

RATIO OF $\frac{\text{CHLORINE}}{\text{AMMONIA}}$ BY WEIGHT	PERCENTAGE OF ORIGINAL FOUND AFTER		
	10 minutes	4 hours	20 hours
Infinity. (ammonia absent)	66.8	40.0	28.1
8 : 1	83.2	77.8	67.3
4 : 1	97.2	94.7	88.5
2.7 : 1	98.3	96.5	92.8
2 : 1	99.8	98.2	96.2

Ratio of 8 : 1 by weight = ratio of 4 : 1 in equivalents.

EVIDENCE OF THE FORMATION OF CHLORAMINE

So far as the author is aware, there is no specific test for chloramine, and although the evidence regarding the formation of this substance from ammonia and hypochlorites or hypochlorous acid, when present in equivalent amounts in dilute solution, is purely circumstantial it must be regarded as fairly conclusive. It has been suggested that the effect of the ammonia is to accelerate or intensify the oxidizing action of the hypochlorite, but this view is contrary to the evidence available. If the oxidizing action were intensified, the rate of absorption of available chlorine by waters containing appreciable amounts of organic matter would be more rapid after the addition of an equivalent of ammonia, but the data at the top of the next page show that the converse holds true.

CONTACT PERIOD	ABSORPTION OF AVAILABLE CHLORINE AT 63° C.	
	Chlorine as bleach	Chlorine as chloramine
minutes		
0	10.00	9.98
5	6.50	9.98
10	5.91	9.90
20	5.18	9.90
40	4.47	9.84
60	3.96	9.88
80	3.65	9.84
1200	•	9.68

The effect of the ammonia in this case was to reduce the rate of absorption to a negligible amount; the amount of chlorine absorbed in eighty minutes after the addition of ammonia is so small as to be almost within the limit of experimental error.

Another method of estimating the effect of the ammonia on the oxidizing power of hypochlorites is by determining the bleaching action on dyestuffs. Indigo, as indigo carmine, is very suitable for this purpose, as it is first oxidized to isatin, a colorless compound, which is then converted to yellow chlorisatin by the action of chlorine. In one experiment it was found that 10 cc. of a bleach solution containing 1 mgm. of available chlorine, after the addition of 10 cc. of warm 25 per cent sulphuric acid, decolorized 13.0 cc. of a weak indigo carmine solution. When an equivalent of ammonia was first added to the bleach solution only 0.2 to 0.3 cc. was required to produce a blue color that was permanent for several hours. Similar results have been reported by Rideal for mixtures of sodium hypochlorite and ammonia and prove conclusively that the addition of the ammonia destroys the bleaching or oxidizing effect of hypochlorites.

Although chloramine has no oxidizing value, it still retains the property of displacing iodine from potassium iodide and consequently gives the usual starch iodide reaction. The chlorine can also be precipitated by silver nitrate and the ammonia determined by the colorimetric method with Nessler's reagent.

Chloramine is very stable in *very* dilute solution and no loss of nitrogen or available chlorine occurs in mixing very dilute solutions of hypochlorites and ammonia, but when the solutions are more concentrated a serious loss of available chlorine takes place on

standing. This is especially marked if there is a local excess of ammonia, such as occurs on the addition of ammonia fort. A bleach solution containing 0.63 per cent of available chlorine lost 14 per cent of available chlorine in twenty hours, and 24 per cent in twenty-four hours, after the addition of dilute ammonia; when ammonia fort was used, the solution lost 89 per cent of its available chlorine in a few hours. On adding strong ammonia to bleach solutions a white precipitate of hydrate of lime is thrown down and a rapid evolution of nitrogen occurs. According to Raschig two competing reactions take place when the ammonia is in excess.

(1) $NH_2Cl + NH_3 = N_2H_4.HCl$ (Hydrazine hydrochloride) and
(2) $3NH_2Cl + 2NH_3 = N_2 + 3NH_4Cl$

When the excess of ammonia is large the second reaction predominates and the yield of nitrogen gas is almost quantitively proportional to the available chlorine in the solution.

Hydrazine has a carbolic coefficient of 0.24 (Rideal) and ammonium chloride has no germicidal action so that if ammonia is to be efficiently employed dilute solutions must be used and a local excess of ammonia avoided.

It appeared possible that chloramine might be prepared by the electrolysis of ammonium chloride but, up to the present, efforts in this direction have not been successful. When warm concentrated solutions are used, nitrogen trichloride (NCl_3) is formed. This is a heavy oily substance that is extremely unstable and highly explosive. When dilute cold solutions are used, a small amount of available chlorine is produced but, owing to secondary reactions which result in the formation of free acid, the concentration does not inerease. This chlorine is not of the nature of chloramine, because such solutions have a decided bleaching action on dyestuffs. When the production of acid is prevented by the addition of ammonia, hydrazine is apparently produced. Another compound of ammonia and chlorine is possible, viz., $NHCl_2$, dichloramine, but its method of preparation and properties are apparently unknown.

The increased germicidal effect produced by adding ammonia to hypochlorites naturally suggests a similar mixture with a solution of chlorine gas but under the usual conditions this apparently has no abnormal value. A typical example of this is shown in experiment 21.

The results are explained by the fact that a solution of chlorine gas in water does not form hypochlorous acid and is consequently

unable to produce ammonium hypochlorite and chloramine. The addition of ammonia to solutions of chlorine gas almost entirely destroys both the oxidizing action and the germicidal action by the formation of inert ammonium chloride. In experiment 21 the effect of this salt is seen in the twenty-four hour results, which show that an aftergrowth of B. coli had occurred which was somewhat proportional to the amount of ammonia added.

MODUS OPERANDI OF CHLORINE DISINFECTION

When bleaching powder is the source of the chlorine the usual method of representing the reactions is by the following equations, in which the nascent oxygen is regarded as the active germicidal agent

$$2CaOCl_2 = CaCl_2 + Ca\,(OCl)_2$$
$$Ca\,(OCl)_2 + H_2O + CO_2 = CaCO_3 + 2HCl + O_2$$
$$\text{or} \quad CaCl_2 + H_2O + O_2$$

Bleaching powder containing 38 per cent of available chlorine has the composition represented by the formula $4CaOCl_2 . 2Ca(OH)_2 . 5H_2O$. When temperature conditions are favorable the chlorine content can be increased to 40 and 42 per cent, but such compounds are not so stable as the one represented by the above formula, which contains approximately 20 per cent of excess hydrate of lime. The stability of bleach solutions depends upon this excess of base (Griffen and Hedallen, *J. Soc. Chem. Ind.*, 1915, 34, 530–532) and although magnesia can be partially substituted for the excess lime a minimum of 5 per cent of lime is required to ensure stability.

Instead of a definite chemical compound, bleach should be regarded as the solid phase of a three-component system which is in equilibrium only under the conditions of temperature and pressure obtaining during its manufacture. Although many of the alterations in equilibrium are of importance, the one of chief interest in disinfection is that produced by the addition of water. The best method of representing this alteration is by the equation $2CaOCl_2 + 2H_2O \rightleftarrows CaCl_2 + Ca(OH)_2 + 2HClO$. which accords with the fact that on distilling a solution of bleach with water or a dilute weak acid such as boric acid, a solution of hypochlorous acid is obtained. It also gives a clear explanation of the fact that ordinary bleach solutions give a higher chlorine content after acidification. It has been stated that when hydrochloric acid is employed the increase in the available chlorine is derived from the chlorine in the calcium

chloride, but this never occurs under ordinary conditions. Weak acids, such as acetic or carbonic acids, will give just as high results as hydrochloric acid. The effect of acids is to remove the hydrate of lime from the right hand portion of the equation and so enable the reaction to proceed entirely in that direction. According to the law of mass action a similar result should be obtained by increasing the molecules of water relative to those of bleach. The author carried out this idea with a 2 per cent bleach solution with the results given in table 4.

The above figures only hold for the particular sample used; other samples containing different excesses of base would give different results.

These results are in accord with the above hypothesis and also show that bleach solutions are entirely dissociated or hydrolyzed at

TABLE 4

Dilution of bleach

PERCENTAGE OF BLEACH IN SOLUTION	$\frac{\text{DIRECT TITRATION} \times 100}{\text{ACID TITRATION}}$
2.0	30.8
0.2	34.3
0.1	41.8
0.02	67.5
0.002	100.0

the dilutions used in water and sewage purification, provided the liquid does not contain substances that impede the dissociation. The dissociation can be reduced by the addition of lime water, caustic alkali or normal carbonate and increased by the addition of any acid that will neutralize and so remove calcium hydrate from the reaction. The effect of chlorides is anomalous and no apparent explanation of their action can be given. The addition of small quantities of sodium chloride (0.1 per cent) increases the dissociation of bleach solutions but much larger quantities tend to have the opposite effect. Bicarbonates increase the dissociation. These observed chemical effects are entirely in agreement with the bacteriological results given in table 1.

A phenomenon of more scientific interest than of practical importance has been noted by Breteau (*J. Phar. Chem.*, 1915, 12, 248) who found that alkaline solutions of sodium hypochlorite con-

taining 0.94 per cent of available chlorine lost 3.8 per cent of their titer on dilution with 80 volumes of water; also that this loss was increased by the addition of small quantities of salt (sodium chloride) and more so by carbonates and bicarbonates. This has been found by the author to hold true for bleach solutions and that the loss increased on standing. It must be assumed that, in dilute solution and in the presence of light, there is a tendency for the reaction $2HClO = 2HCl + O_2$ to occur with loss of available chlorine. Carbonates and bicarbonates would increase the velocity of this reaction, but there is no apparent reason why common salt should have a similar effect.

Sodium hypochlorite is probably hydrolyzed in dilute solution in a manner similar to bleach, $2NaOCl = NaCl + NaOH + HClO$. For solutions containing equal amounts of available chlorine, NaOCl is more dissociated than bleach because of the absence of an excess of base and this, together with the excess of salt, accounts for the slightly higher germicidal velocity obtained with electrolytic hypochlorite. The experience of pulp mills with bleach and electrolytic hypochlorite confirms this; the latter is a much quicker bleaching agent than bleach and it is often so rapid as to make it desirable to reduce the velocity by the addition of soda ash.

The effect of salts and carbonates on solutions of chlorine gas has not been investigated and it is very difficult to deduce them from theoretical considerations on account of the extremely limited ionization of chlorine even in dilute solution.

Both chloride gas and hypochlorite solutions have an oxidizing power equivalent to their chlorine content and both yield 16 parts of oxygen per 71 parts of available chlorine. When a solution of chlorine gas or a hypochlorite is added to water or sewage containing readily oxidizable matter an equivalent of chlorine is dissipated and removed from the sphere of action. This may take place in two ways (1) by the addition of chlorine similar to the oxidation of ferrous chloride to ferric chloride or (2) oxidation by means of nascent oxygen produced by decomposition of hypochlorous acid or by the reaction of chlorine and water. If the reaction took place along the lines of the first suggestion an organic chloro-compound would be obtained in which the chlorine may not react in the usual way with silver nitrate. When bleach is added to the Ottawa River water the whole of the chlorine can be titrated with silver nitrate even after the whole of the free chlorine has disappeared

and it therefore seems probable that the oxidation proceeds in accordance with suggestion 2. There is no reason for assuming, however, that the germicidal action property of chlorine and hypochlorites is due to the production of nascent oxygen for it is well known that such active oxidizing agents as sodium, magnesium, and hydrogen peroxides have a much lower germicidal power than chlorine when compared on the basis of their oxygen equivalents. This is shown in table 5 in which a comparison is made between bleach and potassium permanganate.

In this experiment the chlorine is five times as active as potassium permanganate when calculated on their oxygen equivalents and this value would probably have been much higher if the water used

TABLE 5

Bleach and potassium permanganate. Results are B. coli per 10 cc.

CONTACT PERIOD	BLEACH. AVAILABLE CHLORINE, 0.35 PARTS PER MILLION	POTASSIUM PERMANGANATE		
	Oxygen equivalent parts per million			
	0.08	0.133	0.266	0.40
Nil	140			
30 minutes	90	122	115	110
1 hour	68	115	100	80
1½ hours	63	108	95	75
4 hours	50	95	80	50

had contained less organic matter. Hypochlorites have a much higher germicidal action than can be accounted for by their oxidizing ability and are still more active when their oxidizing activity is destroyed by the addition of ammonia. The germicidal activity must consequently be attributed to some other cause and it seems probable that chlorine and certain of its compounds exert a direct toxic effect on organisms.

Dakin (*Comptes rend.*, 1915, 161, 150–153) from a study of his boricized solutions of hypochlorites iu the treatment of infected wounds has attributed the persistent action to the formation of chloro-amines by the reaction of protein and amino acids with hypochlorites. In a later paper (Dakin and Cohen, *Brit. Med. Jour.*, 1915, ii, 318) he reported the examination of a number of chlora-

mines and found that all substances containing the group: NCl were strongly antiseptic. One of these, paratoluenesulphochloramide, $CH_3.C_6H_4.SO_2.NNaCl$, has been placed on the market under the name of chloramine T and is being extensively used in Europe for the treatment of wounds infected with the gas-gangrene bacillus, B. perfringens. Dilute hypochlorite solutions contain hypochlorous acid and the latter either exerts a direct toxic effect on the organisms or indirectly so after the formation of chloroamines by reaction with the protein and amino acids. Compounds such as chloramine produced by the reaction of hypochlorous acid and ammonia, would by analogy be strongly antiseptic themselves and also exhibit a marked tendency to react with compounds to form others containing the group NCl. It is interesting to note that Cross and Bevan (*J. Soc. Chem. Ind.*, 1908, 28, 260) have shown that chloramines have a tendency to combine with nitrogenous molecules and to become fixed on cellulose. It is possible that the action of chlorine and chloramine is a cytolytic one but the toxic action is probably much greater than can be accounted for in this manner.

CHLORAMINE DISINFECTION IN PRACTICE

At the time when the very abnormal results were obtained with ammonium hypochlorite the discovery appeared to be only of scientific interest and especially so inasmuch as Rideal had attributed the obnoxious tastes and odors sometimes caused by chlorination to the formation of chloramines. During the winter of 1915–1916, however, the price of bleach advanced to extraordinary heights and the author then determined to try out the process on a practical scale for the purification of water. A subsidiary plant pumping about 200,000 imperial gallons per day was found to be available for this purpose and the chloramine process was substituted for the bleaching powder method previously in operation. This was commenced by the addition of pure ammonia fort, in the calculated amount, to the bleach solutions contained in barrels. The results were not what were anticipated and it was found that the bleach solutions as received in the laboratory were far below the strength calculated from the amount of dry bleach used. This experience was repeated on subsequent days and the deficiency was found to increase with increased amounts of ammonia. Solutions of similar strength were then used in the laboratory with similar losses and it

was observed that on the addition of ammonia a copious evolution of gas occurred. This led up to the work reported on page 73 which showed that dilute solutions must be employed and prolonged contact avoided. Alterations were accordingly made in the plant and the bleach and ammonia were prepared in dilute solutions in separate vessels and only allowed to mix for a few seconds before delivery to the suction of the pumps. This method of application was instantaneously successful and results equal to those obtained in the laboratory were at one secured. The dosage was reduced until the bacteriological results were adversely affected and continued at values slightly in excess of this figure for some time to prove that the process was reliable.

The results obtained on the experimental plant, together with those obtained on the main plant, where 20,000,000 imperial gallons per day were treated with straight bleach, are given in the tables 6, 7, and 8. The two periods given are during the spring floods and that immediately preceding it. These represent the worst and the best water periods. The results in both cases are from samples which were examined approximately two hours after the application of the treatment.

The cost data are calculated on recent spot prices for bleach and ammonia (26° B) in the United States, but if the prevailing Canadian prices are substituted the chloramine process shows an even greater economy. The results were so satisfactory that the author recommended the adoption of this method for the main plant and

TABLE 6

Comparison of hypochlorite and chloramine treatment

Bacteriological results

1916	RAW WATER			TREATED WITH HYPOCHLORITE ALONE				TREATED WITH HYPOCHLORITE AND AMMONIA				
	Bacteria per cubic centimeter		B Coli Index per 100 cc.	Bacteria per cubic centimeter		B Coli Index per 100 cc.	Available chlorine parts per million	Bacteria per cubic centimeter		B Coli Index per 100 cc.	Available chlorine parts per million	Ammonia, parts per million
	Agar 1 day at 37°C.	Agar 3 days at 20°C.		Agar 1 day at 37°C.	Agar 3 days at 20°C.			Agar 1 day at 37°C.	Agar 3 days at 20°C.			
March 15–31...	44	238	35.7	4	12	<0.14	0.90	4	12	0.14	0.22	0.11
April 1–19......	3,099	14,408	195.5	32	56	0.50	1.10	33	246	0.74	0.25	0.13

TABLE 7

Percentage reduction

	Hypochlorite alone				Hypochlorite and ammonia			
	Bacteria per cubic centimeter		B. coli index per 100 cubic centimeters	Available chlorine parts per million	Bacteria per cubic centimeter		B. coli index per 100 cubic centimeters	Available chlorine parts per million
	Agar 1 day at 37°C.	Agar 3 days at 20°C.			Agar 1 day at 37° C.	Agar 3 days at 20° C.		
March 15–31	90.9	95.8	99.9+	0.90	90.9	95.0	99.7	0.22
April 1–19	98.9	99.6	99.7	1.10	98.3	98.9	99.6	0.25

TABLE 8

Cost per million imperial gallons

	Hypochlorite alone	Hypochlorite and ammonia
March 15–31	\$1.12	\$0.46
April 1–19	\$1.26	\$0.54

Calculated on Bleach at \$3.80 per 100 pounds and aqua ammonia (26°B) at 5¾ cents per pound.

requested the permission of the local Board of Health to make the change. The matter was referred to the Provincial Board of Health who granted the request provided the chlorine dosage was not reduced below 0.60 parts per million for at least six months. The effect of this would have been to render the treatment more costly than the straight bleach process and consequently nothing further was done. Early in 1917 the Canadian manufacturers again raised the price of bleach, to \$5.10 per 100 pounds, and the permission of the civic authorities was then obtained for the proposed change at the main plant where 20,000,000 imperial gallons per day were being treated with bleach. The ammonia used in this instance was commercial aqua ammonia (26°B) containing approximately 29 per cent of anhydrous ammonia. The material was first examined for the presence of such noxious substances as cyanides and found to be very satisfactory.

The chlorinating plant is situated in close proximity to the low-lift pumping station at the mouth of the intake pipe and at present (April, 1917) discharges a 0.6 per cent bleach solution through a 2-inch galvanized iron pipe to the pumping station, where it is divided up by means of a manifold system and discharged into the

suctions of the pumps. The aqua ammonia is diluted in barrels to approximately 0.40 per cent strength and discharged through an orifice under constant head into the hypochlorite feed pipe as it enters the station. The dosage of bleach and ammonia is determined by the strength of the solutions and by the heads on their respective orifices; and the mixtures of the two is divided among the pumps by regulating the valves on the discharge manifold until the water from all the pumps gives the same intensity of reaction with starch and potassium iodide. The low-lift pumps discharge into a common header from which the intake pipe carries the water to the high-lift pumping station situated some 5200 feet away. Calculated on the average daily consumption of water, a contact period of approximately twenty-five minutes is obtained before the treated water reaches the distribution mains.

TABLE 9

1917	B. coli per 100 cc.		Turbidity	Color	Dosage. Parts per million	
	Raw water	Tap samples			Chlorine	Ammonia
February	268	0.88	3	40	0.57	0.05
March 1–18	250	0.96	4	40	0.32	0.11
March 1–31	643	0.43	4	40	0.47	0.14
April 1–30	5,228	0.14	31	32	0.60	0.10

Early in February the change in the treatment was effected by gradually increasing the quantity of ammonia until a dosage of 0.12 parts per million was reached and constantly decreasing the dosage of bleach, which was formerly 0.93 parts per million of available chlorine. During this period the results were constantly controlled by numerous bacteriological examinations which showed that the results were very satisfactory. When the dosage had been reduced to 0.28 part per million of chlorine, the health authorities intervened, with the result that the dosage was instructed to be increased to the minimum recommended by the provincial authorities. This has so far prevented a thorough test being made of the capabilities of the chloramine process but some results have been obtained that are of interest. The average B. coli results are given in table 9 together with the physical data which show that the April period includes the spring flood period.

At the height of the flood period the water contained 80 parts per million of turbidity and 500 to 1000 B. coli per cubic centimeter yet satisfactory purification was obtained with 0.60 part per million of available chlorine and 0.13 part per million of ammonia. The tap samples at this time averaged 2.5 B. coli per 100 cc. The treated water taken on this day from Hull, where the same raw water is treated with 0.7 part per million of liquid chlorine, gave a B. coli index of 26.7 per 100 cc. and previous experience in Ottawa has shown that under similar physical and bacteriological conditions at least 1.5 parts per million were required to reduce the B. coli index to 2.0. It is very evident that, with normal turbidities of 4 to 8 and a B. coli index of 20 to 50 for the raw water, the 0.6 part per million of chlorine together with 0.10 of ammonia will provide a very generous margin of safety. Even at this excessive dosage the process is financially successful and is saving approximately $8 per day at the present time.

The addition of ammonia has caused no complaints to be made regarding tastes and odors. Chloramine itself has a pungent and penetrating odor that is somewhat similar to that of chlorine but as tastes and odors seem to be associated with the chlorine part of the compound, any method that reduces the chlorine dosage also reduces complaints. This is one of the most valuable features of the new process and one that should commend itself to those who have to treat waters that have small margins between the dosage required for satisfactory purification and that which causes complaints. The chloramine process can be most efficiently employed by using small doses and long contact periods but there is, of course an economical limit to the contact period in water works practice. Waters that are very free from oxidizable matter will probably not give the same relative efficiency with chloramine treatment as that shown by the Ottawa River and on the other hand higher ratios should be obtained with sewage and sewage effluents.

SOCIETY AFFAIRS

MINNESOTA SECTION

A meeting of the Section was held at Mankato on November 10, 1917, with Vice-chairman G. O. House presiding. A paper by F. W. Cappelin on "Advantages of a Local Section of the American Water Works Association" was read by L. I. Birdsall and discussed by Messrs. House and F. H. Bass. A paper on "Some Problems in the Management of a Private Water Company" was read by T. C. Gordon and discussed by Messrs. House, Bass and Whittaker and the author. A paper on "Some Features of Artesian Well Construction in Mankato" was read by H. F. Bloomquist. There were informal discussions of (1) leaks in water mains, (2) labor-saving instruments in water works operation, (3) water distribution problems, and (4) water purification problems.

The following officers were elected: chairman, G. O. House; vice-chairman, H. F. Bloomquist; secretary-treasurer, H. A. Whittaker; trustees, T. C. Gordon, W. F. Todd, L. I. Birdsall.

NEW YORK SECTION

A meeting of the Section was held at the Park Avenue Hotel, New York, on October 18, 1917, with Chairman Allen Hazen presiding and about 75 members and guests present. A paper on the "Catskill Water Supply System" was read by J. Waldo Smith and illustrated by lantern slides. It was followed by an account of the utilization of the Catskill supply, given by H. B. Machen, and a discussion by Messrs. Hazen, W. W. Brush, J. M. Diven, F. T. Kemble and Morris Sherrerd.

A meeting of the Section was held in New York on December 19 at which papers on the water supplies of the National Army Cantonments were read by George W. Fuller and Nicholas S. Hill, Jr., and discussed by Messrs. Allen Hazen, W. R. Conard, J. M. Diven, B. B. Hodgman, J. Waldo Smith and W. W. Brush.

NEW MEMBERS

Active

John F. Clinkenbeard, Water Commissioner, Missouri Valley, Iowa.

Jacob L. Crane, Jr., Assistant State Sanitary Engineer, Lansing, Michigan.

Percy Gray, Pumping Plant Manager, Jefferson, Iowa.

A. E. Hansen, Hydraulic and Sanitary Engineer, 2 Rector Street, New York, New York.

Edgar P. Kable, Assistant Secretary York Water Company, York, Pennsylvania.

John A. Poland, Secretary and Attorney Gas and Water Company, Chillicothe, Ohio.

E. F. Mohrhardt, Secretary Board Fire Underwriters of the Pacific, San Francisco, California.

Earl I. Roberts, State Department of Health, Columbus, Ohio.

C. O. Romig, Secretary and Superintendent Water Supply Company, Denison, Ohio.

Corporate

Department of Public Utilities, Portland, Oregon.

Stockton Water Works, Camden, New Jersey.

Associate

DeLaval Steam Turbine Company, Trenton, New Jersey.

Donaldson Iron Company, Emaus, Pennsylvania.

Portland Cement Association, Chicago, Illinois.

OBITUARY

Joseph E. Fulper, Superintendent and Secretary, Washington Water Company, Washington, New Jersey, December 20, 1917.

Henry M. Hanssen, C.E., Carroll, Iowa, December 25, 1917.

Thomas C. Irving, Jr., Vice President Robert W. Hunt and Company, Ltd., Toronto, Ontario. Killed in Action in France, October 30, 1917.

Homer Dayton Langworthy, Jr., Superintendent Water Works, Macon, Georgia, December 11, 1917.

ROLL OF HONOR

The following is a list of our members and sons of members who are serving with the American and Allied forces:

AMSBARY, HARLOW A. (son F. C. Amsbary), 2nd Lieutenant 6th C. A. C. A. E. F.

BABBITT, HAROLD EATON, Captain Engineers, U. S. R., A. E. F., France.

BARTOW, EDWARD, Major Sanitary Corps, A. E. F., France.

BASCOM, G. R., Major Sanitary Corps, Unassigned.

BASSETT, CHARLES K. (Buffalo Meter Company), 1st Lieutenant Ordnance Department, Washington.

BATCHELDER, ROBERT F. (son G. W. Batchelder), Paymaster U. S. Navy.

BENNETT, A. N., 1st Lieutenant 337th F. A. R. C., Camp Dodge, Iowa.

BERRY, LOREN J. (son J. P. Berry), Sergeant, Medical Corps, A. E. F., France.

BLACK, E. B., Captain Aviation Section Signal Corps.

BLACK, GURDON G., Captain Engineer Corps, Regimental Adjutant, 314th Engineers, Camp Funston, Kansas.

BLAIR, McCREA PARKER, Infantry Commander, Co. G., No. 1 Depot Battalion, M. D. 10, Canada.

BOWLES, JAMES T. B., Major, Sanitary Corps, Surgeon General's Office, Washington, D. C.

BRENNAN, B. C., Captain Engineer Corps, A. E. F.

BROWN, RASSELAS WILCOX, Infantry, Co. A, 112th Regiment, Camp Hancock, Georgia.

BROWN, ROBERT HUSE, Captain Sanitary Corps, N. A.

BUSWELL, A. M., Lieutenant Sanitary Division Medical Corps, A. E. F., France.

CARR, JOSEPH ARTHUR, Aviation Section, Signal Corps, Camp Lee, Virginia.

CATLETT, GEORGE FITZHUGH, Bacteriologist, 26th Engineers, A. E. F., France.

CHENEY, JOSEPH Y., 2nd Lieutenant O. R. C., Co. H, 17th Infantry, Camp Forrest, Ga.

CURRY, DR. D. P. (State Board of Health, Kentucky), Captain M. R. C., Fort Oglethorpe, Georgia.

CHRISIE, J. G. C., Lieutenant Engineer and Construction Department, Aerial Service, Signal Corps, Kelly Field, No. 1, San Antonio, Texas.

CLOW, WILLIAM E., JR. (J. B. Clow & Sons), U. S. N. Training Station, Illinois.

DANIELS, FRANCIS E., Captain Sanitary Corps, Camp Greene, North Carolina.

DAPPERT, JAMES I. (son J. W. Dappert), O. T. C., Camp Stanley, Texas.

DAPPERT, JOHN V. (son J. W. Dappert), 2nd Lieutenant, Headquarters Co. 130 Infantry, Camp Logan, Texas.

DAPPERT, MERLIN L. (son J. W. Dappert), O. T. C., Camp Stanley, Texas.

DAPPERT, ANSELMO F. (son J. W. Dappert), O. T. C., Camp Stanley, Texas.

DIVEN, J. M., JR., 2nd Lieutenant Ordnance Department, Trench Warfare Section, U. S. Filling Plant, Edgewood, Maryland.

DOTEN, LEONARD S., Captain Q. M. R. C., War Department, Washington.

FERGUSON, H. F., 1st Lieutenant 157th Engineers, New York City.

FRITZE, L. A., 1st Lieutenant Field Laboratory, 42nd Division Rainbow, A. E. F., France.

GAVETT, WESTON, 1st Lieutenant Sanitary Corps, Commanding Sanitary Squad No. 1, 28th Division, Camp Hancock, Georgia.

GOODELL, JOHN B. (son J. M. Goodell), U. S. Naval Reserve.

GOODRICK, EDGAR C. (son E. H. Goodrick), Chief Q. M. Signals, U. S. S. *Florida*, in foreign waters.

GRASTY, R. L. (son E. C. Grasty), Infantry Co. F., 158th, Camp Kearny, California.

GWINN, PAUL C. (son D. R. Gwinn), Artillery Co. D., 309th Ammunition Train, Camp Zachary Taylor, Kentucky.

HALE, RICHARD KING, Lieutenant Colonel 26th Division 101st Field Artillery, A. E. F., France.

HANSEN, PAUL, Captain Engineers, A. E. F., France.

HASKINS, C. A., Captain Sanitary Forces, N. A., Fort Oglethorpe, Georgia.

HAZLEHURST, JAMES NISBET, Major U. S. R. Engineers, A. E. F., France.

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INMAN, A. W., Home Guards, Massillon, Ohio.

JARVIS, ALEXANDER CHARLES, Lieutenant Royal Engineers, London, England.

JOHNSON, GEORGE S. (son Peter Johnson), Flying Cadet Aviation, Squadron 13, Signal Corps, Memphis, Tennessee.

KENT, W. T. (son J. F. Kent, Manager American Cast Iron Pipe Company,) Aerial Service.

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LEE, CHARLES H., 1st Lieutenant C. of E., U. S. R., A. E. F., France.

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LEISEN, THEODORE A., JR. (son T. A. Leisen), Naval Reserve, U. S. S. *DeKalb*.

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LUCE, ROBERT F. (son W. H. Luce), Aviation.

McCORMICK, ROBERT, Co. D, 26th Engineers, Camp Dix, New Jersey.

McLAUGHLIN, GEORGE E., Lieutenant U. S. Navy, Assistant Surgeon U. S. Naval Hospital in charge of laboratories, New York.

[1] Killed in action October 30, 1917.

McRae, Henry C., 1st Lieutenant E. O. R. C., Co. C., 318th Engineers, Van Couver Barracks, Washington.

McWilliams, John S. (son C. Q. McWilliams), Aviation, A. E. F., France.

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Mitchell, Charles H., Lieutenant Colonel D. S. O., C. M. G., Chief of Intelligence 2nd British Army, B. E. F., France. Honors: Distinguished Service Order, Companion of St. Michael and St. George, Officer of Legion of Honor (France) Officer of Order of Leopold (Belgium); three mentions.

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Mueller, William Everett (son Adolph M. Mueller Mfg. Co.), A. N. O. R.

Murphy, Alvin R., Captain E. R. C., A. E. F., France.

Murray, Harry E., Captain Q. M. C., Scofield Barracks.

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Pugh, Marshall R., Major 21st Engineers, A. E. F., France.

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Rust, Fred C. (son C. H. Rust), 16th Canadian Reserve Battalion, B. E. F.

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WEST, VERNON F., Lieutenant U. S. Navy.

WILLIAMS, GARDNER S., Engineer Corps, Cantonment Division, Washington, D. C.

WHITMAN, EZRA B., Major and Mayor Camp Meade, Maryland.

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WYNNE-ROBERTS, LEWIS (son R. O. Wynne-Roberts), Lieutenant Royal Engineers, Bangalore, India.

YEARANCE, ALEXANDER W. (son W. B. Yearance), Lieutenant Co. F., 305th Engineers, Camp Lee, Virginia.

VOL. 5 NO. 2 JUNE, 1918

PROCEEDINGS 38TH YEAR

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

PUBLISHED QUARTERLY BY THE

AMERICAN WATER WORKS ASSOCIATION

AT 2419–21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

Vol. 5 JUNE, 1918 No. 2

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The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

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THE CATSKILL WATER SUPPLY SYSTEM[1]

By J. Waldo Smith

Organization. At the time of the inauguration of the McClellan administration, the fact that the consumption of water by the city of New York was rapidly approaching the limits of the existing supply had been pretty well demonstrated by several investigations conducted by the department of water supply, gas and electricity, by John R. Freeman's report to the comptroller in 1900, and by the Burr-Hering-Freeman commission in 1903. Mayor McClellan, with characteristic energy and thoroughness, reviewed all these reports and satisfied himself that it was necessary for the city to secure at once an additional supply of water, and, although other municipal improvements were put forward as necessary and advisable, he chose that of water supply as being most vital to the city's interest and the one which most demanded prompt attention. In the beginning of the second year of his first administration he secured the necessary legislation to make it practicable to proceed at once to determine the best sources from which to obtain an additional water supply and for its construction after the plans were approved.

It had been the uniform custom of the city of New York, when any great improvement was to be carried out, to put it in the hands of a special commission vested with broader powers than those possessed by any of the coördinated departments of the city government, in order that such special work might be more effectively and expeditiously carried out. This precedent was followed, and a board of

[1] Read before the New York Section on October 18, 1917.

water supply, composed of three commissioners, was selected by Mayor McClellan, on the recommendations of certain civic organizations. The statute contained a stipulation that the commissioners could be removed only on account of incompetence or misconduct, proved by hearing after due notice upon stated charges. This provision was designed to insure continuance in office during good behavior and to prevent the change of commissioners with each new city administration. The plan has worked admirably. No commissioner has been removed throughout the progress of the work to date, and only two have resigned, one to retire from active work and one to fill an important state office.

The board appointed the chief engineer. All other appointments in the engineering bureau, as well as dismissals and promotions, have been made by the board in accordance with the chief engineer's recommendations. In no case has a commissioner sought to control or influence these recommendations. This may seem somewhat remarkable in a city which has been so much maligned as the city of New York in past years. This maligning is often done by its own citizens, who, in lecturing throughout the country from time to time, attempt to appeal to the popular prejudice that all public employees are incompetent or dishonest, and make the most astounding statements, with no knowledge of the facts and without even trying to learn them. The author doubts if any other public improvement—national, state or municipal—throughout the country can show a better record.

Preparation and approval of general plan. The chief engineer's appointment took place on August 1, 1905, and a small corps of engineers, about 27, were available by September 1.

The first work in hand was the preparation of a general plan covering an additional supply of water by gravity to the five boroughs of the city. It did not seem advisable to make additional extended investigations as to sources of water supply. Previous investigations and legislative action had pretty well fixed those which might be developed. By utilizing all the information available, and by close application and great energy on the part of the small working force, which was increased to 55 during the month of September, within the space of about five working weeks reconnaisance surveys had been made and a complete plan, including estimates, was prepared, excepting the major part of its delivery system within the city. This plan was approved by the board of water supply and submitted

on October 9 to the board of estimate and apportionment for approval. With the exception of some minor modifications this is the plan which has been carried out. The original estimate, exclusive of the part of the delivery system which was omitted, was $162,000,000. A year or two later studies for the delivery system were completed, and the additional cost estimated at $15,000,000, making the estimate for the entire work $177,000,000. This estimate was made with practically no subsurface investigation. Although there have been many changes in legislation, such as the 8-hour law, the law providing for the establishment of the aqueduct police, and the provision for the payment of indirect and business damages, all of which tended to add to the cost, in an amount estimated to be from $8,000,000 to $20,000,000, it is believed that the work will be completed within the original estimate. As the matter stands today, the actual disbursements and liabilities are $139,000,000. A liberal estimate for completing the unfinished work is $37,000,000, making a total of $176,000,000, or $1,000,000 less than the original estimate, without allowing any credit for the additional expense imposed by legislation.

The approval of the board of estimate and apportionment was secured within the minimum statutory limit of two weeks, and it then remained to obtain the approval of the state water supply commission, which was created simultaneously with the board of water supply and was given general supervision over the sources of water supply to be chosen. Application to the commission was made promptly, and hearings were held, extending over six months. After securing additional legislation to cover indirect and business damage and police protection the general plan was approved by the state water supply commission, in June, 1906, thus making it possible to proceed with the surveys and investigations necessary for the preparation of the construction contracts.

Prosecution of work under contract. The construction contracts were put forward rapidly, so that the first contract, for 11 miles of aqueduct in the vicinity of Peekskill, was awarded in March, 1907. The largest contract on the entire work, that for the main dams of the Ashokan reservoir, of a value of over $12,500,000, was awarded in August of the same year. Other contracts were prepared as rapidly as possible, so that all those involving a large volume of work outside the city were operative before the end of 1909. The main contracts for the delivery of water within the city were awarded in 1911.

Delivery of water to the city. The first water was actually delivered to the city on December 27, 1915, and thereafter a small quantity was delivered throughout that winter and intermittently during 1916. The general delivery of water to all boroughs began in January, 1917. The first delivery of water was made at least a year sooner than was anticipated, and it would have been possible at any time since April, 1913, to deliver water for an emergency period through the Croton aqueduct, had necessity arisen.

Working force and expenditures. The maximum force in the engineering bureau at any time was 1348, in 1911. The maximum labor force employed on all contracts at one time was 16,229 in the same year. The largest expenditure in any month was $3,900,000, in June, 1911, and for one year was $25,900,000 in 1911.

Completion of contracts. The following facts are pertinent. All the construction work, about $100,000,000 in value, has been accomplished by the original contractors or their legal representatives, without the intervention of the city or a call on a surety company to advance money. The author wishes it could be said that the contractor had made a fair profit in every case, but this is probably too much to expect. Difficulties were encountered, due in some cases to low bids, and in other cases due to failure of the contractor to adopt the best methods for doing the work. That the latter was the fact in some cases was very plainly brought out by the operation of contiguous contracts, for the same class of work under approximately the same working conditions, where one contractor, at a lower price, has made a handsome profit, while another, at a higher price, broke even or made a small profit, and in some cases operated at a large loss.

None of the contracts contained provisions for doing work other than that directly provided for in the items of the contract. While it is believed that there should be in contracts provisions for doing extra and additional work, with suitable safeguards, in order to afford greater elasticity, such provisions were debarred by the representatives of the law department. In spite of this handicap, the work was accomplished without the embarrassment of having to suspend operations on a single contract in order to have work done which had not been anticipated or provided for.

Completion within estimated cost. The amounts paid under all the construction contracts, aggregating $100,000,000 in value, averaged approximately 5 per cent less than the amount bid. This is not

claimed to be a saving, as some have tried to make it appear. Nevertheless, it has had a good effect on the public mind because the dear public is prone to consider that any additional expense over the amount bid on a contract is due to incompetence in the preparation or to collusion on the part of those executing it and that such excess is always an increase in the cost. As a matter of fact, we know that the actual cost is neither increased nor decreased.

Importance of preliminary investigations. Believing that very thorough investigations were absolutely essential as a preliminary to the preparation of contracts for construction work and that failure or serious complications are quite frequently due to lack of such preparation special effort was made to have the preliminary inevestigations as thorough and exhaustive as was consistent with economy. Investigations in connection with the location of the dams and of the aqueduct line required the making of 14 miles in depth of wash borings, 31 miles in depth of core borings, the excavating of numerous test shafts and trenches and the making of 3400 miles of preliminary surveys. All this information was exhaustively studied and analyzed. This thoroughness was all the more essential for the preparation of contracts in which there could be no provision for doing other work than that specifically provided for under the items of the contract. The contract and specifications, in the course of their preparation, went through the hands of the most skilled workers in headquarters, and they were also particularly examined by the engineers in the field, who would execute the work, before being put into permanent shape. It was due to this carefulness, and this alone, that it was possible to conduct the whole work, a large part of which was prosecuted under the surface of the ground, without meeting any unforeseen difficulties which had not been anticipated and provided for. Many an undertaking has been wrecked, or seriously hampered, by untimely haste in beginning work, before thorough preparation was made, in response to the popular demand for the "dirt to fly." Due to the great business activity during the early years of the work, or to some kind Providence, this misfortune was averted. The contracts and specifications, as prepared, were intended to give the fullest information to bidders. No attempt was made to conceal or belittle any of the difficulties which were anticipated; instead, an effort was made to emphasize them, and the men in field were instructed to call the attention of prospective bidders to any physical condition

which would affect the execution of the work or the prices to be bid.

Payment items. The contracts contained specific payment items for much work usually included in general expense, and an effort was made to provide a payment item for all work which could be reasonably segregated and measured. The work included in each item and the method of measurement and payment for same were carefully set forth, with the intent of preparing contracts and specifications, which, so far as possible, would eliminate controversies and differences of opinion. This could be successfully done to only a limited degree, for it is impossible to write in this language so that it will be interpreted in the same way by all readers.

Construction of dams in sections, with drainage systems. The building of the dams in sections, with transverse joints about 80 feet apart, has prevented cracking through the body of the masonry on account of contraction, and has incidentally served as an aid to construction, both as to safety and convenience. The masonry between the borders of the drainage system is so impervious that it is uncertain whether this drainage system would be effective or not. As a matter of fact, practically no water runs into it except at the expansion joints. From this experience the author is inclined to eliminate the main drainage system and retain the building in sections.

Construction of steel-pipe siphons. In constructing the steel-pipe siphons, the plates were first pickled to remove all the mill scale before fabrication at the shop. In the field the pipe was laid on concrete saddles carefully set to grade, and after a siphon was completed and full pressure was applied the pipe was completely surrounded with concrete of sufficient thickness to prevent deformation when empty. The pipe was then unwatered and 2 inches of cement mortar placed on the inside. This was accomplished by setting up forms inside the pipe and placing a 1:1 grout around the forms. This resulted in an exceedingly smooth lining, which, up to date, has shown no tendency toward loosening from the pipe. It is believed that this pipe is more completely preserved than by any bitumen coatings previously applied. It certainly provides a much smoother inner surface.

Pressure tunnels. Pressure tunnels are not new. As long ago as the construction of the Croton aqueduct, a pressure tunnel was built from a point north of Jerome Park reservoir to the reservoir

at 135th Street, including the crossing under the Harlem River in the neighborhood of Highbridge. The only marked difference between that pressure tunnel and those constructed on the Catskill work is that the maximum pressure in the case of the Croton was only a little over that due to 100 feet head and that for most of the distance the hydraulic grade was below the level of the ground, or slightly above it, whereas for the Catskill tunnels the average unbalanced head is equal to at least 250 feet and at some points is as high as 425 feet. This enormously increased pressure was the most difficult feature to deal with and one which received exceedingly careful consideration in preparing the design. The result was the establishment of an arbitrary rule that at no point should the sound rock cover for any appreciable distance be less than 150 feet. As a matter of fact, the sound rock cover is materially more than this at practically every point.

The Hudson River crossing. The Hudson River crossing is the most striking example of the pressure tunnel form of construction. The problem of designing suitable apparatus to unwater this tunnel was more difficult than the designing of the tunnel itself. The accepted design consists of two centrifugal pumps of about 5,000,000 gallons combined capacity, each capable of lifting water under a head of about 700 feet and, when arranged in tandem, to raise the water 1100 feet or more, of course with a reduced capacity. This tunnel has been unwatered two or three times with this apparatus with entire success. It is of a portable nature and can be removed to the other pressure tunnels and used in the drainage shafts in a similar way.

Leakage from tunnels. It was anticipated that the leakage from the tunnels in the rock, lined only with concrete, under such high pressures, would be material. It was originally believed that, in the cases of the Rondout and Wallkill Valleys, which are each about 4½ miles across, if each tunnel did not leak more than 1 million gallons daily they would be very satisfactory, probably not greater than from a steel pipe of equal capacity laid in the ground. As a matter of fact, the initial leakage on the first filling was greater, but quickly decreased to a moderate amount and has continued to decrease since, so that the present leakage in all tunnels 36 miles in length, with an interior surface area of 8,700,000 square feet and an average effective outward pressure of 250 feet, is 567 gallons per minute. The leakage of 18 miles is from recent measurements, the

leakage of the city tunnel is estimated from previous measurements. This amount of leakage could be carried through a $1\frac{3}{4}$-inch nozzle under that head.

The city tunnel. A pressure tunnel provided the only reasonable and practicable solution of the delivery of water within the city. The thoroughfares running north and south were already crowded with public utility structures, in the way of gas and electric conduits, subways, etc. Besides this, the inconvenience to the public during construction would have been excessive if it had been necessary to bring this large quantity of water through the city in pipes under the surface. After careful investigations, it was decided to build a pressure tunnel through the backbone of The Bronx and Manhattan Island, crossing the Harlem River, and then the East River to Brooklyn. This tunnel is over 18 miles long, the longest tunnel in the world. This type of construction was also 50 per cent cheaper than delivery by pipes. Contrary to expectation, there have been indications of water at the surface at only two points, at 23d Street and Broadway and at 57th Street and 6th Avenue, and only a very small quantity at each of these points. In cold weather it is most noticeable and at the present time has practically disappeared. One curious matter in connection with the leakage from the tunnels has been observed for at least four years, which is that the leakage varies inversely with the temperature, being at its maximum about March of each year and its minimum the latter part of September, and that both the maximum and the minimum decrease each year. The opportunities for measuring this leakage have been exceedingly favorable, and has been accomplished by measuring in the end shafts of the pressure tunnels at such times as the water is shut off in the aqueduct, this being equivalent to a tank measurement.

When any great project is carried to successful completion, the public likes to believe that one individual is responsible for the success of it, but there is nothing in this view and we all know that success comes, if it comes at all, through the inspiration, confidence and strength, that come with united effort and effective coöperation, on the part of all connected with it. It is certain that any success which may have been achieved on this work is due more to the quality and character of the individuals in the organization than to their leaders. What has contributed most to the effective conduct of the work has been the almost uniform belief and confidence in

one another, the high sense of loyalty and the willingness to sacrifice personal ambition and preferment for the good of the work. All held the good of the work above every other consideration. The policy has been to work with the contractors—not against them; to help and not to hinder. Any other policy means an economic waste. None have been more loyal or more conscientious, or have contributed more to the success of the work.

The author does not claim that this organization has had a monopoly of loyalty, but he does believe that the ties that bind have been a little stronger and more flexible, the sacrifice of personal ambition has been greater and that the loyalty has been more spontaneous and effective. It is certain that association for years with an organization of this character is worth more than any honor or personal preferment which might possibly come to any one, due to his connection with it and its successful completion.

Acknowledgment should be made of the cordial coöperation which has been given by the successive city administrations and by all the men connected with the coördinated departments of the city government with whom we have come in contact. All have been willing to grant the privilege of a hearing at all times. The author desires particularly to acknowledge the very complete coöperation of the chief engineers of the department of water supply, gas and electricity, Mr. de Varona, Colonel Smith and Mr. Brush, and also of the members of their organizations. They have gone out of their way, in season and out of season, to assist in every possible manner. It would have been wrong to have had any other relations between these two departments which are so closely concerned with the water supply of the city, one having to do the planning and construction of the additional supply, which, on completion, devolved on the other department for maintenance and operation.

THE WATER WORKS AT CAMP GRANT[1]

By Charles B. Burdick

Camp Grant, located upon the Rock and Kishwaukee River 5 miles south of Rockford, Ill., is typical of sixteen divisional cantonments constructed to house the National Army. It furnishes accommodations for 36,000 men as originally planned. As completed it provides housing for 42,000 men and 10,000 animals. Each building is supplied with water. Each barrack is accompanied by a lavatory in a separate building also supplied with hot and cold water and equipped with water closets, urinals, wash sinks and shower baths. The buildings total 1520 and cover an area measuring about 3 miles north and south by 1½ miles east and west.

Water supply requirements. The requirements for water supply demanded first, absolute healthfulness, second, adequate fire protection for a rather congested city of wooden buildings, and third, a speed of design and construction that has probably never been equaled for a water supply of the size required.

The instructions to the constructing quartermaster required that water should be provided to the amount of not less than 55 gallons per day per man, or about 2,000,000 gallons per day for the 36,000 men originally proposed for Camp Grant. Instructions further provided that the plant should be capable of delivering water to the distribution system at 2.85 times the above rate, or approximately 5.7 million gallons per day. This was obviously intended to refer to rates for very short periods.

It was required that the water should be furnished under a pressure not less than 60 pounds and not more than 85 pounds unless greater pressures were necessary to distribute the water.

Available supply sources. Northern Illinois is a well watered country and surface supplies are almost everywhere available, but on account of the abundance of ground water, they are seldom used for domestic purposes. A surface water supply at Camp Grant would have been particularly undesirable, even if filtered, on

[1] Read before the Illinois Section on November 15, 1917.

account of heavy sewage pollution in the two streams which border the camp. An investigation was made to determine the practicability of purchasing a supply of water from the city of Rockford, but the quantity available was not sufficient.

There are two sources of ground water everywhere available in the northern one-third of the state, namely, the St. Peter sandstone and the Potsdam sandstone. In most of the river valleys it is also possible to develop water sufficient for a municipal supply from the glacial and alluvial sands and gravels.

The St. Peter sandstone is from 150 to 250 feet in thickness, and in Rockford wells to penetrate it completely would be from 400 to 500 feet deep. A part of the Rockford municipal supply is obtained from this source.

The Potsdam sandstone is much thicker, reaching a thickness of upward of 1000 feet at Rockford. It contains numerous veins of water. The top of the Potsdam sandstone is reached locally at a depth of about 500 feet, and wells about 1500 feet in depth usually are required to fully develop this formation.

The blanket of glacial drift overlying bed-rock varies in thickness in the vicinity of Rockford up to 200 to 300 feet in those places in the valley of the Rock River that were eroded by the ancient stream. In these places the St. Peter sandstone lies immediately below the glacial drift. The glacial drift and river alluvium overlying bed-rock largely consist of sand and gravel and are filled with water below the ground-water plane of the region, which is approximately the level of the streams. Water can be withdrawn from the drift in large quantities where the water-bearing stratum has sufficient depth and porosity. In the city of Rockford the drift in many places is thin and uncertain in character to such extent that no large supplies have been drawn from it, the general practice being to enter the underlying sandstone for all large and moderately large water supplies, such as the municipal supply and private supplies for various manufacturing institutions in the city.

All underground waters of the region are excellent from the hygienic standpoint. All three of the available underground waters are, however, moderately hard.

The time available would not permit of an underground reconnaissance by test borings to determine the most practicable place adjacent to the camp to develop a water supply. Knowing that the sandstone would furnish the required water if it could not be de-

veloped in the drift, it was promptly decided to procure well drilling outfits capable of penetrating the St. Peter sandstone, or going even deeper if advisable. It was further decided to select a locality as favorable as possible so far as surface indications went; to keep an accurate log of the drift materials encountered in constructing the wells, and to utilize a supply in the drift should favorable materials be disclosed in the construction of the permanent wells, otherwise to continue the wells into the St. Peter's sandstone.

It was estimated that with good luck, a St. Peter's well would require about six weeks in drilling. It was further estimated that from six to eight wells would be required to supply the camp. Under these circumstances it would not be practicable to supply the camp by September 1 without employing a number of well drilling rigs. Accordingly, arrangements were made for the rental of four deep-well drilling outfits which were placed at work as rapidly as they could be secured, transported and erected.

The wells. The condition of the pipe market was such that material for private work was practically unobtainable, and pipe for use in well casings was obtainable by the government only with great difficulty and delay. It was early recognized, therefore, that well casings must be ordered at once, capable of completing all necessary wells under the most unfavorable circumstances of the underlying formations that would be likely to be developed in construction.

Under the provision of the general contract, the well drilling outfits were rented by the general contractor under a special contract, the general contractor providing all labor and operating and maintaining the drilling outfits. On account of heavy developments in the oil regions, considerable time was required for the delivery of well-drilling repair parts, and to forestall materials required for maintenance, a supply of drills, cables and other equipment was ordered that would probable be worn out in case it was necessary to drill into the sandstone. One well strainer was provided in order that the first well could be tested should favorable materials be disclosed in the overlying drift.

On June 29, an arrangement was closed with F. M. Gray, Jr., to furnish such well drilling rigs as would be required up to a total of five rigs. The first rig was delivered about the middle of July, and closely followed by two others, and on August 1, three rigs were in operation at depths of 71, 62 and 79 feet respectively.

The first well, after passing through the surface alluvial soil, had entered sand and gravel which continued to a depth of about 90 feet; then the drill passed into clay to 115 feet; then into quicksand and clay to a depth of 135 feet, and then into good coarse water-bearing sand to a depth of 156 feet below the surface. At this point the conditions were deemed sufficiently favorable to insert a strainer and test the well. This was immediately done, and on August 13 the well was tested, producing 311 gallons per minute with a drawdown of 13 feet. It was then decided to develop the drift water supply in the remainder of the wells should equally favorable conditions be found. Favorable materials being encountered three wells were completed during the month of August and two additional wells in September. The last of the six wells was completed October 25.

TABLE 1
Specific capacity of individual wells

WELL NUMBER	PUMPAGE RATE IN GALLONS PER MINUTE	DRAW-DOWN BELOW STATIC WATER LEVEL, FEET	SPECIFIC CAPACITY, GALLONS PER MINUTE PER FOOT OF DRAW-DOWN
1	311	13.0	23.
3	225	10.0	22.5
4	299	8.1	36.8
5	263	10.75	25.
6	286	6.42	44.5
7			18.0

All wells are equipped with Johnston strainers having a No. 40 slot. Four strainers are 10 inches in diameter and 16 feet long. Two strainers are 20 feet long and 8 and 10 inches in diameter respectively.

As is the case with all wells in granular materials such as sand and gravel, the practicable rate of pumpage is directly proportional to the depression of the water surface in the well incident to pumping.

All the 10-inch wells are equipped with 5-inch air lift pumps and pipes having an economical capacity each of 500 gallons per minute. The specific capacities of the wells vary somewhat, but the variation in capacity is taken up in different amounts of drawdowns in the several wells. The original tests of the several wells are given in table 1.

As above stated, the capacity of each well, as developed, is lim-

ited by the air lift installation, and it would be possible, if need be hereafter, to increase the capacity of the well system by installing larger air lift pumps. With the present compressor outfit the plant has shown its ability to produce water at the rates given in table 2.

The lift under which the wells operate varies with the amount of water produced, and varies somewhat in the different wells. Measured from the water surface in the well when operating up to the discharge head, the lift varies from 40 to 50 feet, and averages 42 feet when five wells are in operation furnishing the water supply for the present camp, amounting to about 2,300,000 gallons per day.

The wells were spaced at intervals of 300 feet on centers in order that there may be a minimum of interference, particularly having in

TABLE 2

Capacity of well groups

NUMBER OF COMPRESSORS IN SERVICE	NUMBER OF WELLS IN SERVICE	WATER PRODUCED GALLONS PER MINUTE	GALLONS PER MINUTE PER WELL
1	3	1,376	459
1	4	1,525	381
1	6	2,160	360
2	5	2,470	494
3	5	2,656	531
2	6	2,740	457
3	6	3,300	550

mind the possibility that it might be necessary to go to the Potsdam sandstone for a water supply. The percentage of interference, that is to say, the delivery per foot of draw-down of the group of wells as compared to the sum of the capacities of single wells added together, is approximately 77 with five wells in service. This percentage varies slightly, depending upon the individual wells in service.

Elastic development required. As no time was available to sink test wells and pump them, it was necessary to assume the underground conditions as accurately as possible and to adopt pumping devises that would be workable under any conditions likely to be disclosed in the construction of the works.

Accordingly, it was decided to adopt double pumping, and in view of the possibility that St. Peter's wells would be used, it was

deemed advisable to install an air lift pumping system of sufficient capacity to lift the water, at the demanded rates and height, 100 feet if necessary. At the same time the design was worked out so that it would be reasonably well adapted for pumping a smaller quantity of water against as high a head as 150 feet, or a greater quantity of water against a head of 50 feet or even less.

This general plan of development seemed economical under the circumstances because the probable temporary nature of the supply made it desirable, as a general principle, to pump a few wells to a considerable depth rather than a large number of wells to a less depth. Furthermore, there is probably no means for pumping well water that is more reliable in its operation and that is less likely to derangement than the air lift pump.

For the above reasons the air lift was adopted for Camp Grant. It was decided to install three air compressor units, each capable of pumping 1000 gallons per minute against a total head of 100 feet. This would allow a development of 2000 gallons per minute with one machine in reserve. In the development of the water supply from the drift under a less head, the pump capacities of the compressors are proportionately increased, as indicated by the figures of yield previously shown.

A canvass of the power situation disclosed a very good central generating station in Rockford privately owned, with the practicability of purchasing power on a sliding scale rate. The necessity for a quickly installed plant and the probability of very reliable service from the Rockford installation led to the very early decision to utilize electric power in the water works pumping operations.

As a reserve for use in case the electric power should be temporarily unavailable, an oil engine was installed which could furnish the camp with water for a short time. This pumping unit proved to be very valuable, for it enabled the plant to begin pumping operations about a weak earlier than would have been possible with electric power.

Pumping equipment. Electrically driven centrifugal pumps were adopted for the high lift equipment on account of the rapidity with which they could be furnished, transported and installed. Stock apparatus was used for part of the equipment. The low installation cost per unit of capacity also made this equipment highly desirable in a pumping plant of a more or less temporary nature.

The drilling of the wells, the construction of the concrete reser-

voir and the foundations for the pumping station equipment were begun simultaneously about the middle of July.

The first pumping unit, the oil engine and its pump, was set upon its foundations about August 20, and began pumping on August 25. At this time the building foundation wall only had been completed, and to prevent damage from the weather, the engine flywheel and the belt were covered with a shed constructed of boards and building paper which protected the apparatus until the building was under roof. The air compressors were installed during the last week in August and the first compressor began pumping September 1. The first electric driven pump went into service August 31.

When pumping operations began, the filling around the reservoir was not entirely completed, and the plant started with about 5 feet of water in the reservoir. This was gradually increased as the embankment was completed.

Storage of water. A storage reservoir was adopted intermediate between the low lift and high lift pumps, in order that the well system might be operated as nearly at a uniform rate as possible, thus providing a surplus of water so that the high lift pumps might follow the fluctuating rates of water consumption. This reservoir also serves as a reserve which can be drawn upon for fighting fires. A circular concrete reservoir 16 feet deep containing 300,000 gallons was built for this intermediate storage.

While the average water consumption of the camp should not much exceed 2,000,000 gallons per day, the rate of use at certain hours will probably greatly exceed the ordinary uses of a city, for the reason that all inhabitants of the camp will be subject to the same rules as to the time of arising in the morning, meal hours and going to bed at night. For this reason the use of water, particularly at meal times, is very great, reaching as high a rate as 6,000,000 gallons in twenty-four hours.

In order that these reasonable fluctuations in demand may be taken care of without an excessive installation of machinery, pipes and water supply, it was thought to be desirable to install an elevated tank which, during the peak of the water demand, can feed the system from the center, thus more than doubling the available capacity of pumping machinery and distribution pipes.

Accordingly, a contract was entered into about July 10 with the Chicago Bridge and Iron Works for furnishing and erecting an elevated tank of 300,000 gallons capacity, 140 feet high, from plates in

stock. This company agreed to complete its work by September 15, and it was, therefore, expected that it would be necessary to operate the water supply by direct pressure for about two weeks. The tank was delivered on the ground and erection started on July 28, and by the use of a double force and work during practically all of the daylight hours, the erection was completed on August 20, five days in advance of the completion of the pipe line which permitted the delivery of the water to the camp.

Distribution system. It was early appreciated that the water distribution system, involving 16 miles of mains and 20 miles of service pipes, would require a very prompt delivery of materials and concentrated work to permit supplying water to the troops on September 1. For numerous reasons it was decided at Washington that so far as possible the water pipes should be made of wood.

The wood pipe originally reserved for Camp Grant was rejected and the order cancelled. A rush order for wood pipe was then placed with Pacific Coast mills, and to expedite construction about half the order for 10-inch pipe was placed with cast iron pipe factories and shipped from Scottdale, Pa. Later, to facilitate construction, an additional order was placed for about 3700 feet of 10-inch cast iron pipe shipped from Ohio, and still later, authorization was granted to purchase 10,000 feet of 8-inch cast iron pipe to be shipped from Ohio stock to hasten the completion of the pipe lines.

The valves and hydrants reserved for Camp Grant were provided with the standard bell ends common in water works practice. The wooden pipe reserved for this camp was connected by means of a tenon and a double hub coupling, the tenon being driven into the hub of the coupling. Where special fittings or valves were connected to wooden pipes, or where wooden pipes were connected to iron pipes, a special form of fittings was necessitated. The manufacturer with whom the original pipe order was placed, recommended cast iron fittings with machined hubs of such size as to fit the tenon on the wood pipes, and fittings of this kind were specially made for the work.

Upon the delivery of the wooden pipe from the Pacific Coast it was found that the tenons were too small to make a tight joint in the machined hubs purchased to use with the wood pipe originally ordered. This difficulty was overcome by sawing off the spigots upon certain of the pipe and cutting a new spigot on the ground

after unwinding a few strands of the banding. Later in the work it was found that a passable joint could be made with a standard water pipe fitting without machining, and a large number of such joints were used.

The lack of water pipe during July and the early part of August made it possible to concentrate the work of the trenching machines on sewer pipe laying. Early in August, however, when the sewers were nearing completion, it became necessary to utilize a part of the trenching machines on water pipe, and accordingly, several miles of water pipe ditches were opened, and stood open until pipe arrived.

The first water pipe reached Camp Grant August 14. Considerable difficulty had arisen in holding experienced pipe layers on account of the delayed delivery of the pipe, but as rapidly as possible, the gangs were reorganized. On August 25, the pipe line between the pumping station and the elevated tank, about 6000 feet in length, was completed, and the water was turned in. Since this date the camp has been continuously supplied.

On August 31, pipe lines with attached hydrants had been extended through the northwest and southwest wings of the camp, and moderately good fire protection was afforded to every part of the camp where buildings were completed. On this date, 6 miles of water mains were in place, and 5 miles of water service pipes. By September 12, about 70 per cent of the pipe laying had been done, and shortly after the middle of the month there only remained to lay the pipe supplying the stables, not then authorized, and the additions to the camp occasioned by the remount station and the training battalion. This work was completed during the very unseasonable month of October.

Difficulties. It must not be assumed that the work was carried through without difficulties or disappointments. This was far from the facts. Although everyone tried to anticipate difficulties and provide for them in advance, there were few days during the first six weeks when something wholly unexpected and detrimental to progress did not arise. Space will not permit recording them here, but they were real difficulties at the time, and that some of them did not defeat the purpose of the work is due to the superintendents and foremen, who displayed great resourcefulness in emergencies.

Early in the work, before everyone's powers and duties were clearly understood, there was much in the way of chasing up blind

alleys and coming out again before the right path was found. The good nature displayed by everyone in these encounters was surprising. In fact, it was a feature of the work from first to last, that in case of error everyone searched for the remedy rather than a "goat" to place the blame upon, and it was this spirit among the men engaged that made this strenuous work a pleasure.

PROGRESS REPORT OF THE COMMITTEE ON SANITARY DRINKING FOUNTAINS[1]

In response to the active popular demand a large number of manufacturers are now offering for sale so-called sanitary drinking fountains. This means that a very wide variety of types of fountains is now available. In any town or city many different types will probably be found. In a recent investigation at the University of Minnesota out of 77 drinking fountains 15 different types were found. Two general classes of fountains are now on the market, the intermittent flow type and the continuous flow type. Each of these general classes may again be subdivided into two subclasses: those with suitable mouth guards and those without suitable mouth guards.

Most of the fountains now available seem to have been designed with reference to appearance rather than to the laws of sanitary science. Although many of the fountains are extremely neat and attractive in appearance, nevertheless with a little thought they will be found to provide small security against the transmission of contagious diseases. Some of the fundamental principles which most fountains violate are as follows:

First, the fountain should be so designed that the lips of the drinker may not touch the metal top of the bubbler. In spite of this self-evident fact, it was discovered last year in a canvass of the catalogs of 39 manufacturers that only 6 of them appreciated the importance of this detail, since only 6 of these 39 provided suitable mouth guards for all of their fountains.

In order to demonstrate the need of mouth guards, your committee employed an observer to inspect the use made of two fountains without mouth guards. One fountain was of the continuous flow type with a bubble $\frac{5}{8}$ inch in height. It was located in a public library. During the period of observation 59 persons drank from the fountain, 22 of whom were children, and 37 adults. Of the 22 children, 15 placed their lips upon the metal top of the bubbler in

[1] Read before the Iowa Section at its annual meeting, October 10–12, 1917, at Council Bluffs.

drinking, while 7 did not. Of the 37 adults, 28 placed their lips upon the metal top, while only 9 did not. One adult had an eruption upon the face, and one was apparently in bad general health.

The second fountain was of the intermittent flow type with a bubble $\frac{3}{8}$ inch in height. It was located at a street corner. During the period of the observation 43 persons drank. One was a small child that had to be held up in order to drink. This child placed its lips upon the metal top of the bubbler. Of the remaining 42 persons, 18 were children, and 24 adults. Ten of the 18 children placed their lips upon the metal top, while 8 did not. One of these children was apparently in bad general health. Nine of the 24 adults placed their lips upon the metal top, while 15 did not.

Such facts are conclusive evidence of the need of mouth guards. Any observer may easily obtain his own evidence of this need by watching the use made of fountains without mouth guards in his own town.

Second, no fountain should be so designed that the incoming bubble of water passes through a cup of contaminated water which cannot drain out. Many of the new drinking fountains in the State of Iowa are of this type. Actual experiment has found that when coloring matter is added to these cups, it is retained for long periods of time before the fresh bubble passing up through the cup of water has removed all of the stain. Of course the bacteria from the lips of the drinker may readily fall back with the escaping water into the cup and seriously contaminate it. Such a contamination would exist for a long period of time before all traces of it had disappeared.

Third, in the case of bubble fountains without mouth guards no effort seems to be exerted to maintain a height of bubble sufficient to permit easy drinking without resting the lips directly upon the metal top of the bubbler. This is usually the fault of the owner of the bubbler and not of the manufacturer. It may, however, be the fault of the manufacturer in case he has not provided a pressure regulator which is so designed that an ample height of bubble will be maintained for ordinary variations in pressure in the service pipe of the fountain. This is an especially important point in the case of school buildings where at recess times or between classes large numbers of fountains are in use at the same time. This lowers the pressure in the service pipes considerably and a well designed pressure regulator on each fountain becomes an absolute necessity.

Fourth, fountains should be so designed that the water which

has touched the lips of the drinker cannot be retained by the fountain long enough to endanger the next drinker. With the present vertical jet type of fountain, if it is designed upon the intermittent flow principle, when the flow is stopped after a drinker is through, the water in contact with the lips falls back upon the top of the bubbler. If the bubbler is then in the act of draining out, some of the contaminated water may be drawn within the bubbler itself. In any case, it runs over the surface of the bubbler, making it possible to deposit thereon disease germs or particles of mucous membrane. In the case of vertical jet fountains, designed upon the continuous flow principle, it would seem at first thought that no danger of this kind would exist. Of course such a fountain, if it had an undrained cup, might violate the second principle of design noted above and be a continual source of danger.

The following question, however, is not yet satisfactorily answered: Is a properly designed, continuous flow, vertical jet fountain dangerous, and if so, why? Experiments upon such a fountain, made in the laboratory of medical bacteriology at the University of Wisconsin in 1915 shows real danger. The bubbler tested was an ordinary continuous flow type, consisting of a perforated top which screwed into the center of a hollow metal bulb. The experimenters washed out their mouths with suspensions of B. prodigiosus, and then without touching the metal portions of the fountain, drank from a bubble 2 to 3 cm. in height. In one case the bacterium thus introduced was recovered after one hundred and thirty-five minutes. The average maximum length of time which the bubble retained the organisms was twenty-five minutes. The reason why these organisms were retained for so long a time has not been demonstrated. The theory has been propounded that these organisms danced upon the column of water much as a ball dances upon the top of a garden fountain. It seems to your committee that more experimental evidence is necessary in order to show that the continuous flow, vertical jet type of fountain, if properly designed, is so dangerous as this one set of experiments seems to prove. Accordingly your committee would ask that it be continued another year in the hope that it may find the time to conduct a series of experiments along this line.

So far as your committee is aware only 4 manufacturers have as yet realized the dangers lurking in the vertical jet type of fountain. Within the past few weeks one of these manufacturers has placed

upon the market a new type of nozzle. This nozzle throws a jet at a slant and the nozzle itself is so protected that it cannot be contaminated. The nozzle is designed after the drawing by H. A. Whittaker, Director, Division of Sanitation, Minnesota State Board of Health, published in the Public Health Reports, vol. 32, no. 19, p. 695, May 11, 1917.

The laboratory investigations thus far have all shown the inherent danger of the vertical type of bubbler. The experiments at the University of Wisconsin on one occasion showed 43 out of 77 bubble fountains, or 55.8 per cent, to be contaminated with streptococci. On a second occasion 35 out of 50 fountains were found to be contaminated with streptococci, 70 per cent of the total. The immediate occasion for starting these investigations at the University of Wisconsin was an epidemic of streptococcus tonsilitis which occurred in the fall of 1914 in one of the women's dormitories. In seeking to find the source of the spread of this epidemic the drinking fountains were examined and found to be heavily contaminated with streptococci. Similar investigations at the University of Minnesota found that of the 77 drinking fountains in use 80 per cent were infected with streptococci.

A bibliography is appended to this report, giving all the references to papers on sanitary drinking fountains with which your committee is acquainted.

Conclusions. First, all drinking fountains should have suitable mouth guards. Second, sanitary fountains of the intermittent flow type with the vertical jet are unqualifiedly condemned. Third, sanitary drinking fountains of the continuous type, with a vertical jet, even when properly designed, would seem to be possible factors in the spread of contagious disease, if the Wisconsin laboratory experiments are confirmed by further tests. Fourth, the slanting jet type of fountain with the nozzle properly protected is perfectly safe, simple in design, and inexpensive to purchase. A design is already on the market which may be attached to any of the present type of drinking fountains. Fifth, your committee asks to be continued in order that it may make further investigations, particularly with reference to continuous flow bubblers of the vertical type.

Respectfully submitted,

J. H. Dunlap, *Chairman*,
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CENTRIFUGAL PUMPS[1]

By E. C. York

The trend of the times in power plant equipment shows plainly a movement from the reciprocating toward the rotary type of machine, whether turbine, motor, blower or pump. The centrifugal pump is one of the important developments in this evolution. Its low initial cost, small repair charges, durability, and high pumping elasticity, compel instant recognition. But if there is one machine which demands a full knowledge of its peculiar limitations, it is the centrifugal. A single pump used at constant speed for a wide range of capacity and lift is inefficient and unreliable, for the centrifugal pump gives its best results only when intelligently designed for each specific condition of operation, in accordance with the results of years of careful experimentation and consequent improvement. This evolution enables the manufacturer to guarantee better results than have hitherto been practicable, particularly as regards the multi-stage or high-lift pumps, which, as now made, are adaptable for many purposes not hitherto considered the field of centrifugal pumps. By reason of compactness, elasticity and high power, they afford a solution of pumping problems perplexing many engineers and their use makes it possible to materially reduce pumping costs.

The first centrifugal pumps had impellers with single radial wings, and these have developed into the more efficient enclosed or shrouded impellers. The combination of two or more separate centrifugal pumps in series, each discharging into the suction of the succeeding one, is not new, and very satisfactory results have been obtained for some time with this arrangement. It does away with the division sleeve between the first and second stage impellers, which is a source of a very large percentage of loss, for this sleeve becomes worn rather rapidly. There is no way to take up this leak except to remove the sleeve and replace it with a new one with new bush-

[1] Read before the Minnesota Section April 21, 1917.

ing, which at the present cost of bronze metal is a somewhat expensive job.

When purchasing a centrifugal pump there are five points of prime importance which every buyer should investigate most thoroughly:

1. Reliability of the pump in service.

2. Efficiency, including provisions for maintaining the original efficiency.

3. Life of the pump, or its ability to resist wear and corrosion, and the ease and cost of repairs when deterioration occurs.

4. Accessibility of all internal parts and ease with which inspection or repairs can be made without special tools.

5. Methods of manufacture, reliability of guarantees, accurate test and general service given by the pump manufacturer.

It is quite evident that several of these factors are in a measure dependent on others, and also that a pump to give the best possible results must combine all five of them. In the selection of hardly any other class of mechanical equipment do all these considerations need more careful attention on the part of the purchaser than in the case of pumps, for the reason that a machine handling water or other liquids must resist not only the usual mechanical wear but also the corrosive and erusive action of the liquid.

Reliability of operation and a constant and adequate supply of water are of great importance in any water supply system. It is therefore essential that the machine be one that will operate continuously without shut-downs or delays from mechanical troubles, and one that will not require constant and expert attention on the part of the operators. In the design, the question of reliability should be given first consideration, and each and every part should be so made that its operation is certain and dependable. The bearings should be large and carefully made, and the arrangement for lubrication should be given particular attention. Balance, both mechanical and hydraulic, should be adequately provided for in order to avoid the gradual deterioration always resulting where there is vibration. All parts of the machine should be made of such materials and of such strength that they are rugged and suitable for continuous operation for long periods.

The efficiency of a pump, or in fact of any machine, is of importance. The life of a pump is measured not only by its ability to resist wear and deterioration but also by the ease and convenience

with which it may be repaired and thus restored to its original efficiency. High efficiency maintained for a short time is of no particular value, as true economy is a matter not only of the initial efficiency, but also of the ability of the machine to maintain this efficiency, and of the ease, convenience and cost with which the owner can re-establish the efficiency after the machine has been in operation for such time as necessarily causes parts to become worn or damaged. The question of accessibility is thus coupled with that of efficiency, for the reason that the machine that is easily accessible is more likely to be inspected from time to time by the operator, so that its interior condition will become known.

The design, workmanship and materials employed in a pump should be such that the original efficiency will be maintained for the longest possible period. For this reason, the engineer should not recommend cast iron impellers, because such impellers are corroded rapidly and wear much faster than the bronze impeller, resulting in a marked decrease in efficiency. As the working member of the pump the impeller exercises the greatest influence upon the efficiency. It must be properly designed, with correct surfaces and smooth finish, and it must be of material which will withstand wear and maintain the original form and smoothness. The type used in centrifugal pumps should be the inclosed or shrouded impeller, in which the blades are located between side plates, forming inclosed passages.

The type of wearing ring is also of great help in maintaining the original efficiency. The greatest leakage occurring in a centrifugal pump is from the discharge chamber to the suction chamber, between the impeller and the casing. Leakage at this point is not ordinarily detected, even when excessive, and in many pumps, causes a considerable reduction in the pump capacity and efficiency. Ordinarily this joint is formed between cylindrical surfaces concentric with the shaft; the leakage path is therefore straight and presents little resistance to the flow, and the clearance space discharges as much water as would an ordinary plain orifice of the same area subjected to the same pressure difference. The engineer should realize the great practical advantages to be secured by reducing the leakage in centrifugal pumps as much as possible.

Very desirable results have been obtained by the labyrinth type of division rings, consisting of two removable rings, one attached to the pump casing and the other to the revolving impeller. Each

ring should be made to standard gages so that it can be replaced without fitting. The intermeshing grooves form a labyrinth, or tortuous passage, through which the water must pass in order to escape from the discharge to the suction chamber. The many bends in the path of the water create additional resistance to its passage, which, with the greater absolute length of the path, greatly reduces the leakage as compared with that with straight rings. The rings should be of bronze, the same material as the impeller.

Manufacturers have abandoned the use of diffusion vanes, as it was found that they deteriorate rapidly, which results in marked decrease in efficiency. They greatly complicate the interior of the pump, introduce a number of separate pieces and internal joints, rapidly become worn and eroded, particularly at the tips (which should be finely formed) and are ruined by solid bodies, such as stones, sticks or gravel, jamming between the tips of the blades and the pump impeller.

Efficient, reliable and accurate methods of manufacture by a builder of centrifugal pump equipment are of value to a purchaser in many ways. The essence of the matter is that high grade machines can be produced only by a shop using high grade methods, tool equipment, inspection and testing. Neglect of these vital matters may entail heavy expense and great annoyance later, which will far offset any possible saving in first cost. High grade workmanship and materials are not necessary for the successful initial mechanical operation of a centrifugal pump, but they are essential to long life and maintenance of efficiency and are thus of great importance in future years.

In 1910, the management of the Minneapolis water department decided to increase its pumping capacity. To this end, a thorough study was made of different types of pumps. The Minneapolis General Electric Company submitted a proposition to furnish electric power for an electrically driven pump on an "off the winter peak load basis," which included the months of November, December, January and February only, at a flat rate of $4 per 1,000,000 gallons pumped to the reservoir against a total head of 240 feet, with a combined motor and pump efficiency of 72 per cent.

Largely on account of this offer, the Water Department asked for bids on two 20,000,000 gallon two-stage electrically driven centrifugal pumping units, and also on one 20,000,000 gallon vertical triple expansion pumping engine. The bids received on the triple

expansion engine varied from $88,000 to $106,000. The Henry R. Worthington Company's bid of $28,665 was accepted for two 20,000,000 gallon electrically driven, two-stage pumps of the single casing type. The contract specified that each two pump was to be driven by a 1200 horse-power, 60-cycle, three-phase, 2200-volt, slip ring induction motor, with an efficiency on full load of at least 94 per cent. The rise in temperature of any part of the motor, after a full load run of twenty-four hours, should not be more than 40°C. The combined pump and motor efficiency was guaranteed at 75 per cent.

The Minneapolis General Electric Company signed a ten year contract to furnish power at the price mentioned. The two pumps were turned over to the city in April, 1912, and have been in constant service since, except, of course, for the necessary time for repairs. The pump at the Northeast Station has been running three years without a single shut-down for repairs and with only about 1 per cent reduction in efficiency in three years. The Camden Station pump, however, has had to be overhauled annually on account of sandy water, which causes a drop in efficiency of about 5 per cent a year. On this account it is very necessary to make provision for renewing or repairing the wearing or division rings.

It has been found practicable, when the ring or the impeller becomes worn enough to require renewing, to take the impeller out, face the surface in a lathe, and renew the ring in the pump casing to fit the turned down impeller. The old set is put away for future use, and when the impeller ring is worn enough so that it will not admit of further wear, it is faced for the last time, a resurfacing ring shrunk on to take the wear, the old set of casing rings bored to fit, and practically a new pump results. The tips of the impellers do not wear enough to affect the efficiency of the pump and the casing shows no material wear.

It is worth while to give the stuffing boxes some attention, especially where there is sand or grit. The difficulty has been overcome at Minneapolis by using filtered water to seal the glands.

The operation of the centrifugal pumps has shown a considerable saving over the triple expansion units in the items of labor and maintenance. This saving was estimated at the time of installation as possibly $10,000 a year; five years' experience has proved the saving even higher than originally estimated. It amounts practically to $1.50 per 1,000,000 gallons pumped to the reservoir, or about $15,000 per year, according to present rate of consumption.

METHODS OF DETERMINING AND PLOTTING METER CAPACITIES AND SOME RESULTS[1]

By Fred B. Nelson

The relative merits of meters may, in general, be shown by a comparison of their accuracy, sensitiveness, durability and capacity.

Accuracy is an important, in fact, an essential feature easily determined by test and the only one to which the average city gives serious consideration. Yet there is hardly a meter on the market that cannot meet the usual accuracy requirements, particularly the positive displacement type of meter in which accuracy, only, calls for little refinement of design beyond an accurate fit of the piston in its chamber. The feature of accuracy, therefore, gives very little as a basis of comparison of the different makes and types and creates little or no competition.

Sensitiveness or ability to register low flows is a feature which represents revenue in the registration of the small and often continuous flows which exist on nearly all classes of services, and is a feature in which the different makes and types differ more and upon which more competition could be established by city requirements.

Durability is not so susceptible of determination by test, but accelerated tests can be arranged which, in a short time, will more or less duplicate the service wear of years, and in justice to the efforts of meter companies in putting out durable products, greater recognition of this quality should in some way be made by more specific requirements.

Capacity, the fourth feature, is one which is susceptible of exact determination and one in which surprising differences are revealed between the different makes in the same size and often between the proportional capacities of the different sizes of the same make. It is a feature which has a direct bearing on the service pressures maintained and requires careful and intelligent designing if high capacity and relatively low loss of head are to be secured and the other essential features retained. Yet it is a feature that is quite generally

[1] Read before the Richmond Convention, May 10, 1917.

ignored and little incentive is held out to meter companies to perfect their products in this direction.

Recent meter testing of the department of water supply, gas and electricity of New York has been conducted with considerable attention to pressure loss and capacity, and the author feels that certain features of the methods used and the results obtained may be of interest.

The apparatus used consists essentially of the following: A mercury U-tube so connected by tubing with the inlet and outlet of the meter as to measure directly by the head of mercury the pressure loss between those points at the different rates of flow; tank scales for determining by weight the actual volume of water passed; a regulating valve for adjusting rates of flow; a quick-acting valve for starting and stopping the tests with a minimum of flow below the adjusted rate; and a stop watch for the accurate determination of the duration of flow.

The three elements, pressure loss, volume and time are thus obtained by single readings of apparatus having a very small percentage of error and the results are surprisingly consistent. The use of the mercury column in particular, by giving one direct and sensitive reading of the pressure difference, eliminates the mechanical inaccuracies of pressure gauges and many possible errors, due to the attempt to make simultaneous observations of two gauges, apply corrections and substract their readings. One pound per square inch of pressure corresponding to 0.455 inch of mercury deflection enables a very accurate direct reading of the pressure loss even on very low flow, which could hardly be taken with any degree of accuracy by subtracting the readings of two gauges.

Apparatus embodying these features was assembled and used by the author in making pressure-loss tests on all disc meters on the New York approved list and others submitted for approval in all sizes up to and including 2 inches.

In studies of pressure loss and capacity, the author feels that it may be of interest to call attention to some decided advantages in the use of logarithmic paper in plotting pressure-loss data and some features of pressure loss that are by that means illustrated. This paper is so ruled that equal distances, horizontally and vertically, correspond to the logarithms or powers of the numbers given on the ruling, so that in plotting any data in which one value varies as a fixed power of another, the graph or curve is that of the constant

ratio between the powers of the indicated values and is therefore a straight line.

The advantage in the use of this paper in plotting pressure loss is due to the fact that the pressure loss in meters varies very closely as the square of the discharge, so that if discharge values be plotted horizontally and corresponding pressure losses vertically, the points will define a straight line having a slope of one horizontal to two vertical. From this it follows that from but one correct determination of pressure loss at any given rate of flow, the pressure loss of all other rates of flow is at once determined by drawing a straight line through the one plotted point at this 2 to 1 angle (compare figs. 1 A and 1 B).

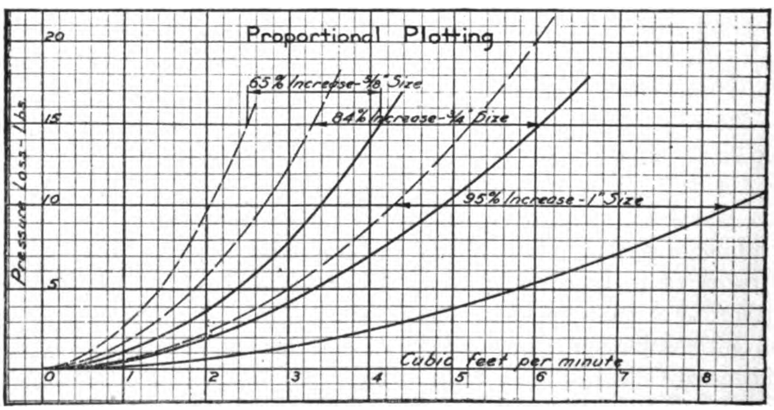

FIG. 1 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY REDESIGNING AND ENLARGING OF WATERWAYS WITHOUT CHANGE IN DISK SIZE; PROPORTIONAL PLOTTING

The slope of this line (2 to 1) represents the general law of pressure loss in disc meters and is therefore the same for all makes and all sizes, and the lines or graphs for individual meters of all makes and sizes are parallel (fig. 5). In the tests made, such a line has frequently been drawn from a determination at but one flow and afterward a different desired rate of flow has been adjusted to within 1 or 2 per cent by a turn of the regulating valve, bringing the mercury column to the pressure loss corresponding to the intersection of that line with the desired rate. The straight line also serves as a check against all errors of computation or reading where more than one determination of pressure loss is made, as the points must theoretically fall on

a straight line and any errors in results are at once conspicuous by the points plotting up off the line.

The disadvantage of the logarithmic plotting is that the values are not shown in their true proportions. Where, however, a proportional curve is needed it can easily be constructed in a few moments

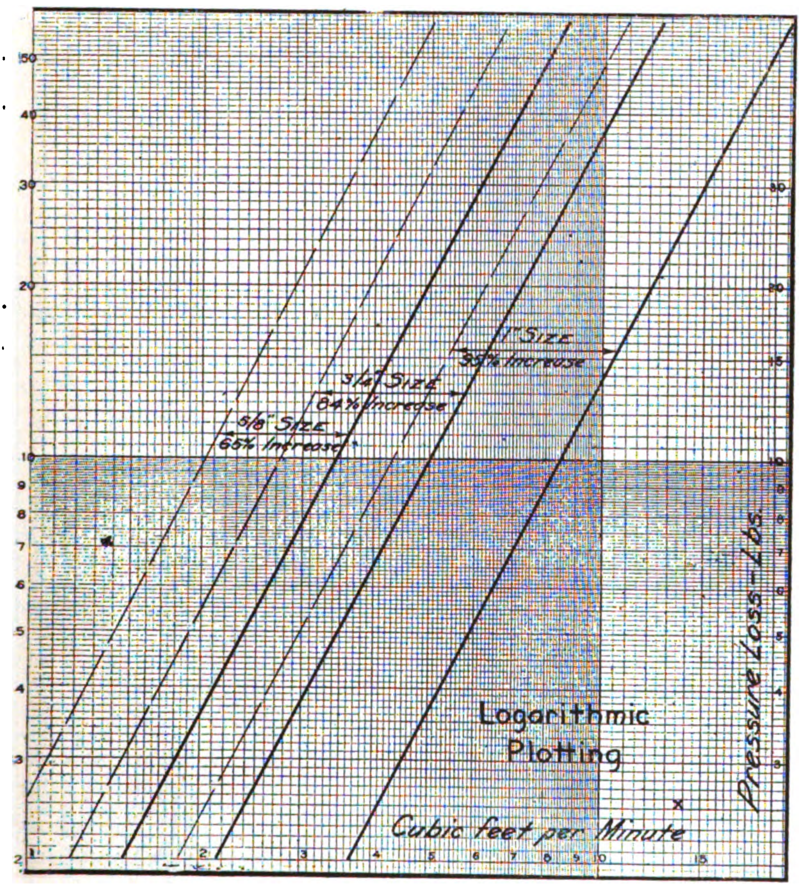

FIG. 1 B. SAME DATA AS FIG. 1 A—*Logarithmic Plotting.*

by plotting any desired number of points taken from the logarithmic line, with a consequent saving of a great amount of time otherwise required to obtain a sufficient number of test points in the ordinary way, including the essential low flows, to define the pressure loss curve well.

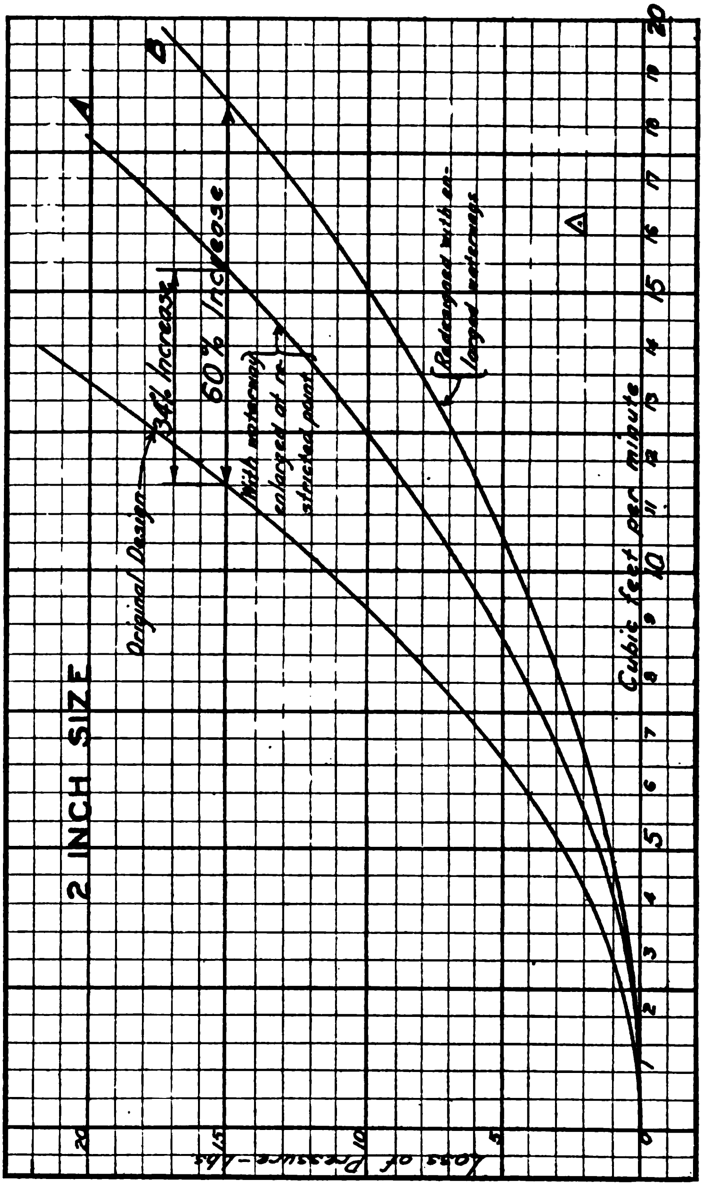

FIG. 2 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY IMPROVED CHANGES ORIGINAL METER, CURVE A, AND BY ENLARGED WATERWAYS EMBODIED IN IMPROVED COMMERCIAL TYPE, CURVE B

As a point of interest the slope of the straight line graph on logarithmic paper verifies the correctness of the formula that friction loss varies as the square of the flow. In the actual tests made this has been indicated to vary from the 1.94th power to the 2nd power of the rate of flow.

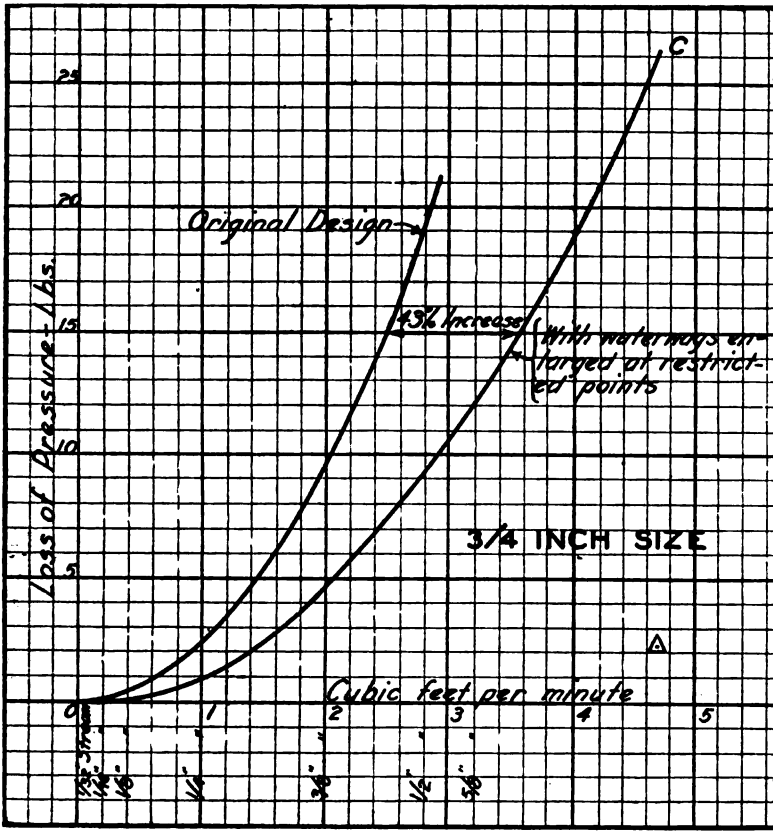

FIG. 2 B. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY ENLARGED WATERWAYS IN IMPROVED COMMERCIAL TYPE, CURVE C

Convenient use may be made of the logarithmic method of plotting in comparing the relative capacities of the different sizes in any one make (fig. 3—A, B, C and D. If diameters be plotted horizontally and corresponding areas of orifices vertically, the plotted points

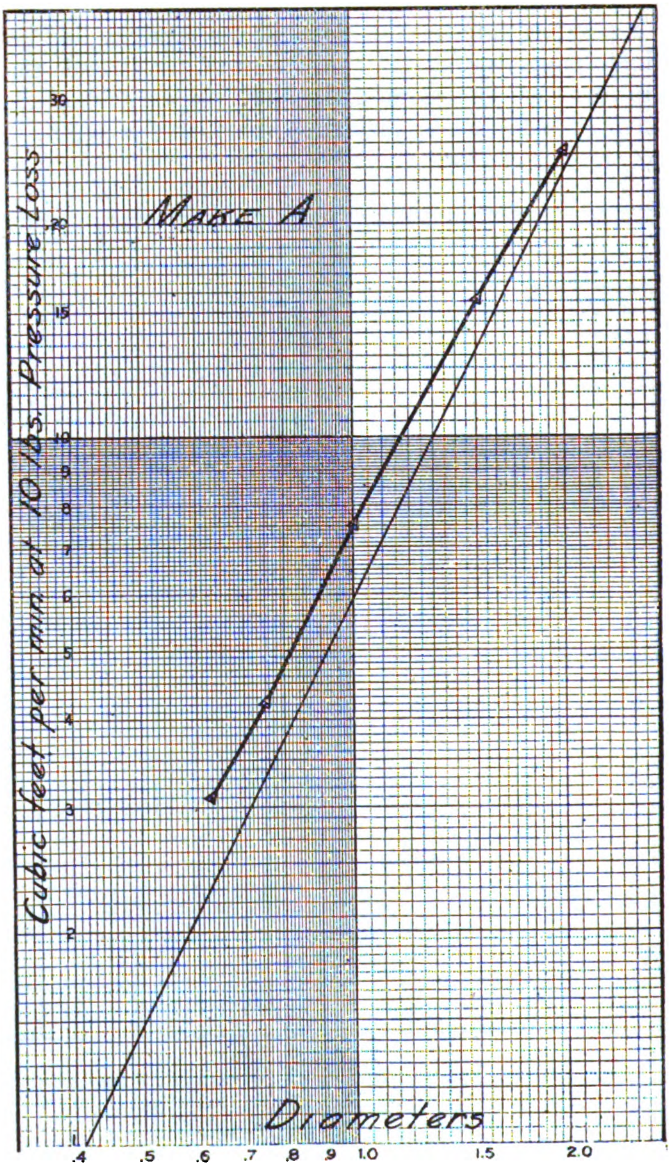

FIG. 3 A. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER FIXED HEAD; WELL-PROPORTIONED METER OF HIGH CAPACITY

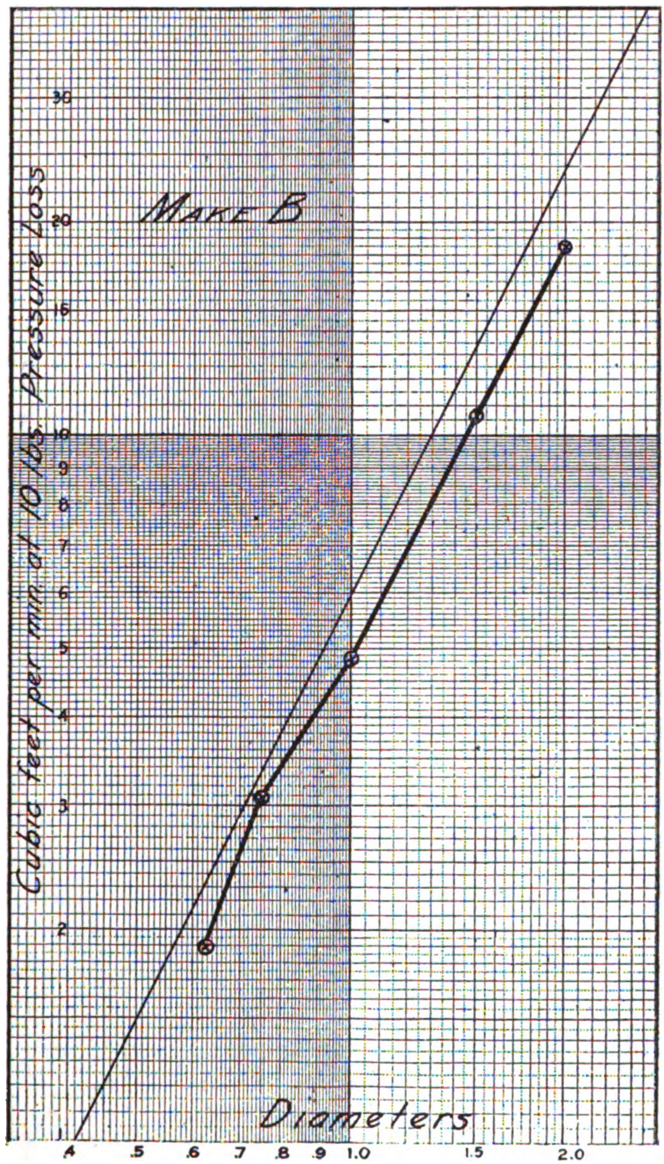

Fig. 3 b. Proportional Capacities of Meters at 10 Pounds Pressure Loss Compared with Proportional Discharge of Similar Sized Orifices under a Fixed Head; Well Proportioned Meter of Low Capacity

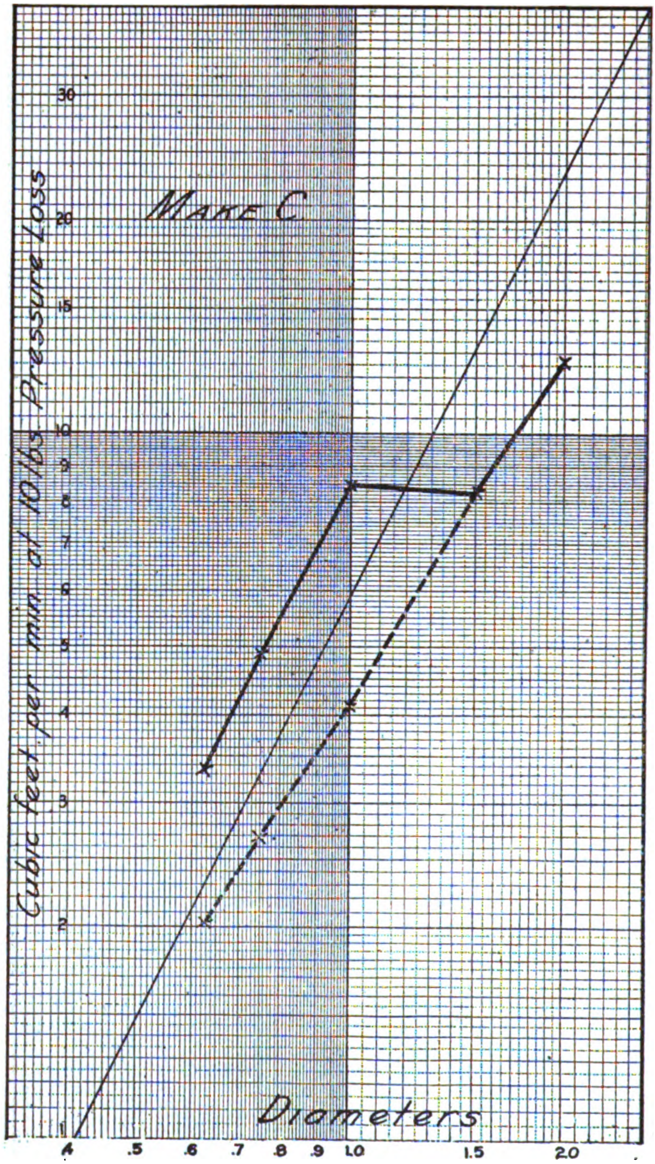

Fig. 3 c. Proportional Capacities of Meters at 10 Pounds Pressure Loss Compared with Proportional Discharge of Similar Sized Orifices under a Fixed Head

The full line shows the present proportional capacities of improved $\frac{5}{8}$, $\frac{3}{4}$ and 1 inch sizes as illustrated in Figure 1, and the dotted line shows the capacities of the original design.

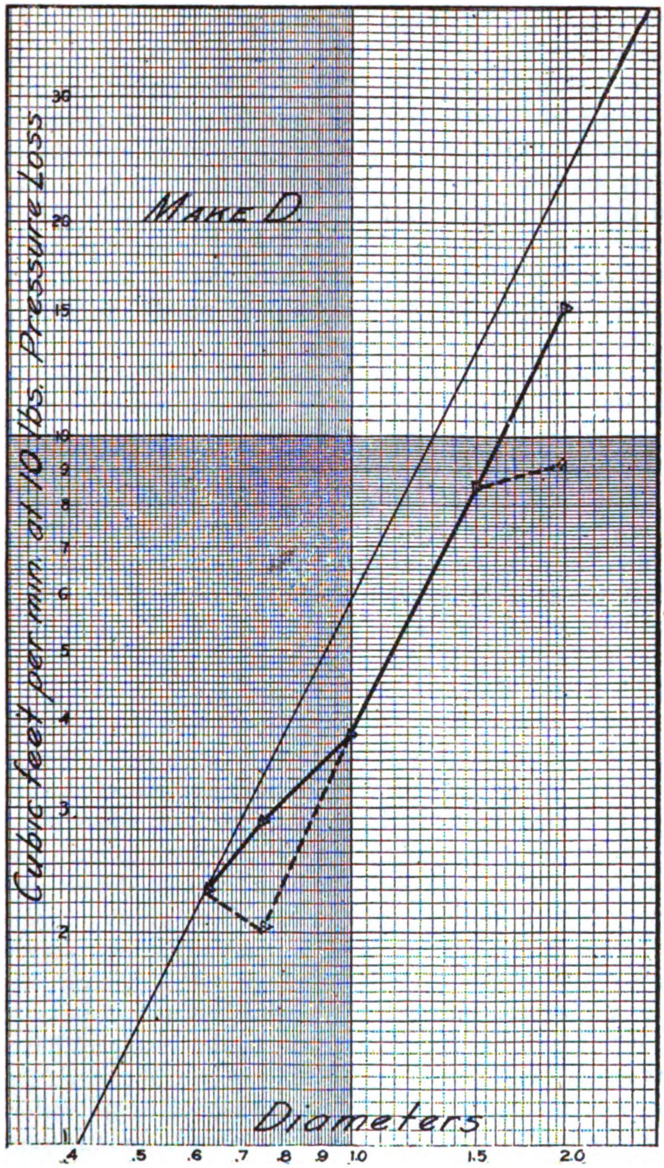

Fig. 3 d. Proportional Capacities of Meters at 10 Pounds Pressure Loss Compared with Proportional Discharge of Similar Sized Orifices under Fixed Head

Dotted lines show the variation from ideal proportions in the original designs which were rectified by the increases of capacity shown in Figures 2 a and 2 b.

will define a straight line with a slope of two vertical to one horizontal, the area and consequent discharge under a fixed head varying as the 2nd power of the diameter. Using the same horizontal scale of diameters, the cubic feet per minute discharge of each size of meter may be plotted vertically. If now it be assumed that the capacities of one type and make of meter should vary in proportion to orifices of corresponding sizes, then these plotted capacities should also define a straight line which should be parallel to that representing areas.

By such studies of capacities it is shown that a very wide variation exists in the relative capacities of the different sizes of some makes (fig. 3) as well as an extremely wide variation in the capacities of different makes in the same size (figs. 4 and 5).

There are a number of features of design which at once suggest themselves as affecting capacity more or less directly and in some cases these features seem to have been sadly neglected. In the tests made the capacity seems to be but slightly affected by size of disc and number of mutations, except, possibly, in cases where the total friction loss is small and the disc size and speed enter in as an appreciable part of the total loss. In most cases, the size and shape of the waterways have far more direct bearing on the capacity. In the construction of pumping machinery, great emphasis is placed on easy curves of waterways and very gradual changes of direction in the flow of water, particularly on suction lines where but little friction loss can be permitted. Some meters seem to have been designed with the same care and attention to these details, while in others very little attention seems to have been given. Frequently waterways are so restricted as to act as partially closed valves and often the course of the water is abruptly reversed, both features resulting in a serious increase of pressure loss and decrease of capacity. On the tests that have been made, instances have been noted where the capacity of the meter has been increased from 34 to 95 per cent merely by a change or redesigning of the waterways, leaving the size of the disc, number of mutations, etc., the same (see figs. 1 and 2).

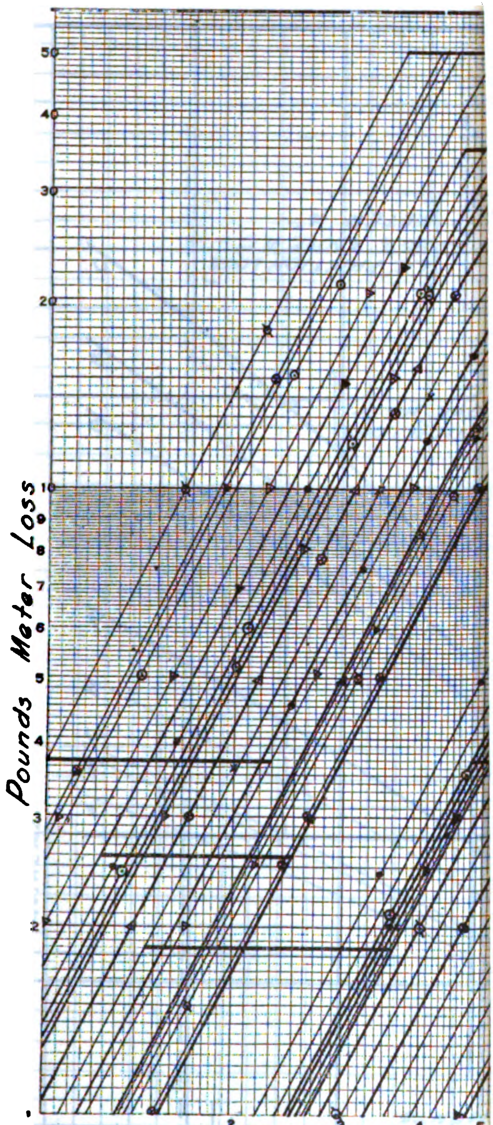

FIG. 5. COMPARATIVE PRES
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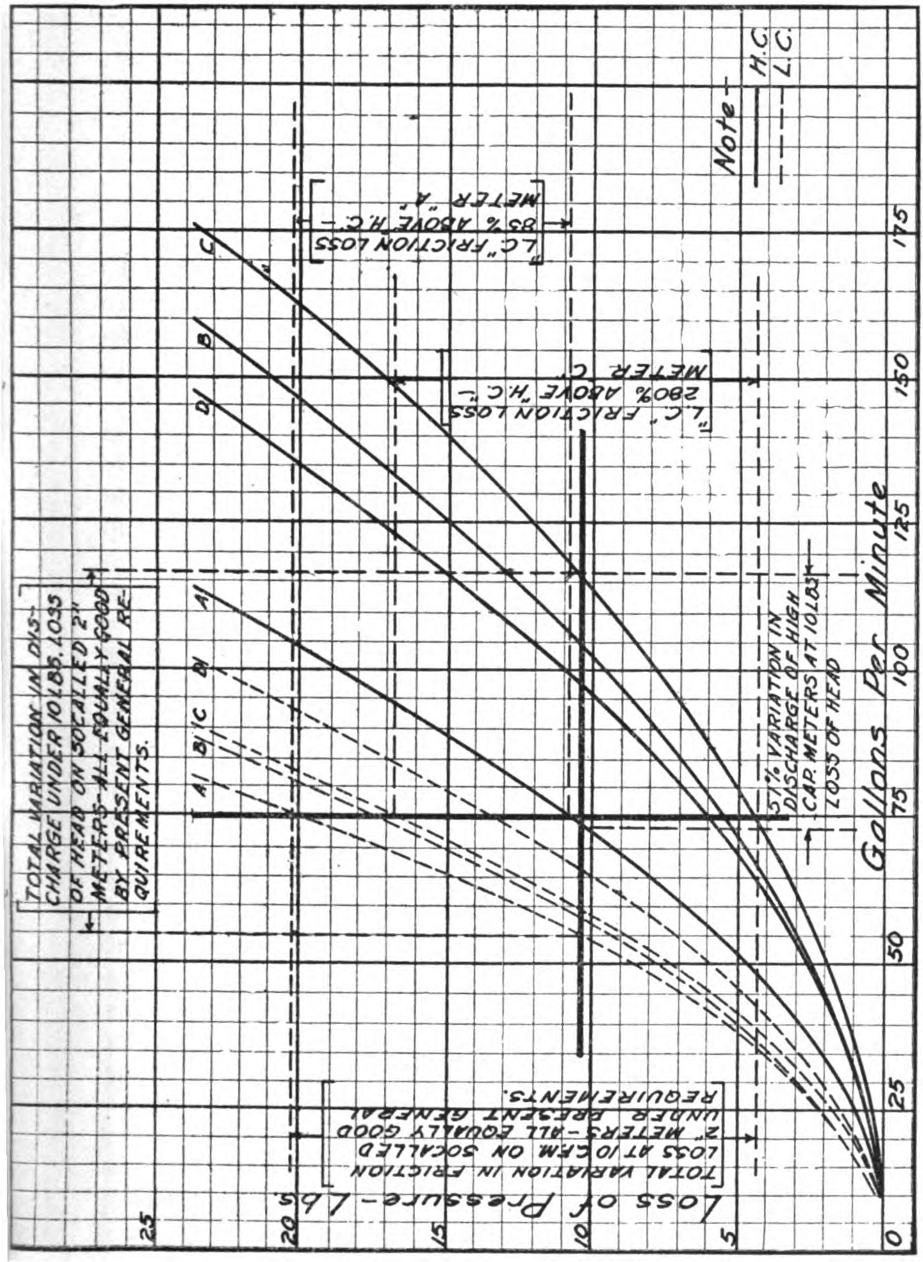

FIG. 4. VARIATIONS OF CAPACITY AND LOSS OF HEAD IN FOUR MAKES OF 2-INCH METERS
Full lines are for high-capacity and dotted lines for low-capacity meters.

WATER PURIFICATION PROLEMS[1]

By B. M. Mohler

There are in Minnesota at the present time seventeen public water supplies which are receiving some kind of purification. Nine of these supplies are treated with chlorine gas only, two receive filtration and subsequent disinfection and six are subjected to sedimentation, filtration and disinfection.

The Duluth water supply is the only one of the group treated with chlorine only, the treatment of which is not difficult to properly control, the Lake Superior water showing only slight variations in physical characteristics. The other eight supplies in this group show considerable seasonal variation in organic content and are difficult of proper control, especially wherever facilities for necessary laboratory tests are lacking.

The Minnesota state board of health insists that purification of a contaminated public water supply by disinfection only is merely a temporary expedient and that a suitable system of filtration must be installed as soon as possible to supplement the disinfection treatment.

Seven of the seventeen supplies are treated with calcium hypochlorite solution while the remaining ten are disinfected with liquid chlorine. Trouble has been experienced in five instances by the sticking of the float in the meter of a certain type of chlorinator which necessitated the control of the flow of gas by weighing of the chlorine cylinder at stated intervals. This latter method of control is not accurate when there is any considerable variation in the amount of chlorine gas required. Experience has shown the need of keeping on hand a supply of duplicate parts for chlorinators. A duplicate chlorinator is desirable for use in cases of emergency.

[1] Abstract of paper before the Minnesota Section, November 10, 1917.

AMERICAN WATER WORKS LABORATORIES[1]

By Jack J. Hinman, Jr.

The water works laboratory as an integral part of the up-to-date water works plant is so well established and has proved itself so useful that any attempt on the author's part to justify its existence is unnecessary. It is only where the small size of the plant forbids the expense attached or where an invariable ground water is supplied that the lack of daily laboratory control should be excused.

While an experienced operator will probably be able to judge the character of the water supply on most occasions, there are, nevertheless, times when a clear, sparkling water may be carrying large numbers of bacteria some of which may be pathogens, or disease-producing forms. The only way to know the quality of the effluent is to submit it to a laboratory examination. At best the delays incident to cultural methods are considerable, but to pump a dangerous water until typhoid cases commence to develop in a community before having examinations undertaken is inexcusable. The number of examinations which it is advisable to make will depend, naturally, on the supply. If the supply is from deep wells, fewer examinations will be required than where the supply is from shallow wells and infiltration galleries. Where a polluted water is coagulated and filtered, examinations should be made even more frequently than in the case of the shallow wells and infiltration galleries. It should be remembered that a dangerous water is being treated and that the character of the effluent may change from day to day or even from hour to hour.

Then, too, the mere installation of a laboratory does not confer immunity from raw water troubles or even from the more serious difficulties. An accumulation of glassware collecting dust is of no value, neither is an accumulation of figures which have no significance from the standpoint of the quality of the effluent or of the effective operation of a plant. Most analysts run a few thousand nitrogen determinations on the raw water before realizing that the

[1] Read before the Iowa Section, October 10, 1917.

results do not vary enough from day to day to be of any practical value. To run them as a routine measure in such cases is a waste. Under certain conditions, of course, there may be considerable daily variations in the nitrogen factors. It is essential that the variable factors be recognized, so that changes in the raw water may be detected and the treatment altered to meet the new conditions. More elaborate examinations of the treated water are justified as giving additional evidence as to its satisfactory character.

For some time the author has been curious to know about the water laboratories which serve the various water plants directly. He was not so much interested in the laboratories that did work under contract or with those that made occasional examinations. He wished to know what plants maintained laboratories, how extensive they were, how they were organized, what their routine procedures were and what results were obtained. He sent out a very comprehensive questionnaire to all cities of over 25,000 population in the United States and Canada, as well as to some smaller places where he knew laboratories were maintained or rapid sand filtration plants installed. Only those which reported plant or department laboratories are included in this report. Contract laboratories and plants operating without laboratory control are not included in the tables.

The percentage of replies was very good. There are only four or five towns of special interest which failed to answer the letters. The author has data on an average daily pumpage of more than 3,000,000,000 gallons, of which more than 2,800,000,000 gallons, supplying cities and towns of a total population of about 17,000,000 in 1910, is protected by laboratory control directly under the supervision of the water works officials or their superior officers.

In the control of the 96 plants which supply the 2,800,000,000 gallons of water daily, 203 laboratory workers are employed. Of these, 95 have the title of chemist or assistant chemist, many of the others have the title superintendent of filtration or laboratory director, and so on. Some of these men have had chemical training. Some are engineers who have picked up the rudiments of water examination and carry on such determinations as are necessary for their plants. The preponderance of one-man laboratories is significant and the variety of the work which must be performed is worthy of notice. In addition to the widely differing subjects of bacteriology, microbiology and chemistry of water, miscellaneous chemical

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and bacteriological work must be entered into. If the laboratory man is also an engineer, so much the better.

The author was surprised on first preparing his record to see how recently the laboratories listed had been installed. Beginning with the one maintained by the city of New York since 1897 and that of Utica, N. Y., established in the same year, a rapidly increasing number of laboratories was established during the succeeding 19 years. Six plants with a combined averge pumpage of 32.5 million gallons per day are now installing laboratories.

TABLE 3

Increase in laboratory control of water purification plants by plant or department laboratories

YEAR	AVERAGE DAILY PUMPAGE, HUNDRED MILLION GALLONS	POPULATION, 1910, MILLIONS	NUMBER OF PLANTS
1897	5.6	5.8	2
1898	5.6	5.8	2
1899	5.8	5.9	3
1900	5.8	5.9	3
1901	5.8	5.9	3
1902	6.2	6.05	.5
1903	6.3	6.1	6
1904	6.6	6.4	8
1905	6.9	6.65	10
1906	.0	7.5	15
1907	8.6	7.9	17
1908	8.8	8.15	19
1909	9.5	8.85	26
1910	10.9	9.75	34
1911	11.4	10.1	41
1912	12.0	10.6	50
1913	13.1	11.5	57
1914	13.7	11.75	61
1915	14.7	12.50	74
1916	14.8	12.65	77
1917	15.5	12.75	83

Twelve plants with a combined pumpage of 45,000,000 gallons per day have daily examinations made at outside laboratories. The Metropolitan Water District which supplies Boston and some neighboring communities is under a state commission. It maintains its own laboratory and supplies a little more than 100,000,000 of gallons of water daily.

Of the plants reporting, 23 are owned privately, 72 municipally and one by the United States government. The employees of 29 of

the municipally owned plants and those of the government plant are selected by civil service methods.

Rivers and streams form the direct source of 68 plants out of the 96 that have their own laboratories, the remaining sources are lakes, impounded waters from more or less satisfactorily protected watersheds and, in a few instances, wells and infiltration galleries. Those plants which do not maintain laboratories are nearly all using the water of wells or impounding reservoirs. None of them supplies more than an average pumpage of 16,000,000 gallons per day. One or two pump directly from streams without treatment.

The quantity of the laboratory work done as well as the particular determinations made are dependent upon local conditions. For instance, there is very little use in determining iron every day unless the raw water contains that metal in sufficient quantities to precipitate or aid the growth of iron-secreting organisms.

Color and turbidity are usually determined on the raw and treated supplies if the water is coagulated and filtered. These factors give a somewhat rough indication of the efficiency of the treatment. Alkalinity is another common determination, since it limits the amount of coagulant which may be put into a water without the addition of alkaline substances such as lime, soda ash or bicarbonate of soda. Free carbon dioxide is carefully watched in some plants, particularly those that soften the water, remove iron, or use the iron and lime process. Incrustants and other matters are determined where the conditions justify.

Occasional complete sanitary chemical examinations are usually considered sufficient, since chemical standards based upon the ordinary factors of a sanitary analysis often mean very little when applied to the routine examination of a treated water. As a matter of fact the oxidation of nitrogen in one of our rapid sand filters is almost negligible and any evidences of pollution which appear in the raw water will be but slightly modified. This state of affairs has led to error on the part of individuals who have attempted to judge a treated water upon the basis of the commonly stated chemical standards. In the case of stored or impounded waters considerable oxidation may take place and the determination of the nitrogen factors may become of greater importance.

Mineral analyses are valuable to users of water for steam-making, but those individual firms which enter seriously into the problem of softening a supply usually make their own determinations of a few

important factors. There are quite a few boiler plants in most communities which use proprietary boiler compounds, prepared upon the basis of special analyses by the manufacturers of the compounds or upon the examinations of the laboratory of the water plant. Of course, an analysis of the city water showing its excellence for all industrial purposes is a good advertisement.

In general, however, it may be said that a quarterly mineral analysis, a weekly or monthly sanitary chemical analysis and routine determinations of color, turbidity, temperature, alkalinity, free carbon dioxide, free chlorine and the like, ought to meet all demands for chemical examinations. In discussing chemical determinations, very little reference to the procedures is necessary since the procedures laid down in the Standard Methods of Water Analysis of the American Public Health Association are so universally followed.

Plankton examinations are made by but 32 of the plants listed. In many cases they are not necessary. Where water is impounded or stored in open reservoirs, routine plankton examinations are useful in indicating the proper time for copper treatment before odors and tastes due to algae growths have become objectionable.

When working with a treated water, the bacteriological determinations are of the highest importance. In most instances they determine the efficiency and adequacy of the treatment given. The arbitrary standards of efficiency applied to water treatment are rapidly becoming more and more rigid. The original filters which the New Chelsea Water Company of London installed about 1829 were considered efficient if they merely removed the turbidity of the Thames water. Then a good many years later came Koch's standard of a maximum of 100 bacteria per cubic centimeter. This standard was applied to water of all kinds. Later a standard based upon a percentage removal of bacteria came into vogue. The percentage standard of plant efficiency is not satisfactory, because when one is treating a good raw water the product may show a low percentage efficiency and yet actually be of the best quality. On the other hand when the raw water is high in bacteria the effluent may be high also and still be within the limit set up. For example, 99 per cent efficiency in the operation of the Iowa City plant at one time last winter would have allowed a bacterial count of 8,800 because the raw water had a bacterial count of 880,000.

Within the past year or so, Wolman of the Maryland State Board

of Health has proposed a logarithmic ratio standard which has some advantages. It requires that the ratio of the logarithm of the number of bacteria in the raw water to the logarithm of the number of bacteria in the treated water shall not be less than 2.5 to 1. In effect it requires that as the contamination of the raw water increases, the efficiency of operation must increase at a more rapid rate. This standard undoubtedly has its limitations but it is a convenient device for supervision of operation of a number of plants.

At the same time that the strictly numerical bacterial standards of operation have been evolving, other standards based upon the freedom of the water from certain kinds of bacteria, such as the colon bacillus and the sewage streptococci, have been developing also. In this country the sewage streptococci have been worked with but little, while in Europe, particularly in Germany, the validity of American conclusions based upon work on the B. coli has been questioned. The author believes, however, that the present European tendency is to place more faith in the B. coli determinations than in the past.

There exists considerable difference of opinion as to the maximum number of bacteria of the colon type which may be allowed in safe water. The presence of B. coli in 1 cc. quantities of the water, except occasionally found organisms, is generally recognized as sufficient to condemn a supply. In addition it has been said that it should be absent from the majority of 10 cc. samples of the treated water. Constant absence in 5, 10, 50 and even 100 cc. has been recommended. A few years ago the United States Treasury Department standard for water supplied to trains carrying passengers in interstate traffic was promulgated. Briefly this standard required that a water should not contain more than 100 bacteria at 37°C. and that not more than one out of five 10-cc. plantings of the water into lactose broth should show the colon bacillus. This was practically equivalent to setting a limit for colon at one in 50 cc. This standard was adopted as the majority report of the committee appointed. It aroused considerable opposition from the water men when first adopted, but the government officials explained that it was not intended for city supplies, but for the small amount of water supplied to passengers. Since then it has been required that bottled spring waters and mineral waters should pass this Treasury Department test.

In the last column of table 1, under the head "Working Standard,"

are given the standards which the officials of the different plants have set up for their use. Many of these are working to the Treasury Department standard, a few are working to even higher standards, while some mention only a removal of turbidity and color. The author is inclined to believe, however, in these latter cases that some standard of bacterial purity was intended to be understood.

Some of the standards listed are very high and with some waters would be practically impossible to achieve except at a very high cost. This points to the fact that arbitrary standards are apt to be unjust in that they require all waters to reach a certain degree of purity which may not be essential to the safety of the supply.

The practical uniformity of procedure which can be noticed in the chemical determinations of a water analysis has not existed in the bacteriological procedures, due in part to the changes and ambiguity which were introduced by the committee into the second edition of the *Standard Methods of Water Analysis*. The third edition, which was published in 1917, is furnished with a much clearer statement of bacterial methods and no doubt will aid materially to clear away the confusion which exists.

In considering the methods used, the least variation will be found in the plating, because the possibilities for variation are not so great. In the body temperature determinations some workers use litmus lactose agar, which gives the opportunity of recognizing acid-forming bacteria in addition to the count, and others use the plain nutrient agar. At 20°C., many of the older laboratories use gelatine while others employ agar on account of its lack of trouble with liquefiers and its general convenience. In some laboratories the 37°C. or body count is omitted, while in more laboratories the 20°C. count is omitted on account of the recommendation of the committee in the second edition of *Standard Methods*. Fortunately the third edition has restored the 20°C. count.

In regard to the colon bacillus, there is the greatest diversity of method. Some are satisfied with gas formation in dextrose or lactose broth at the risk of calling a considerable number of tests positive when the gas formation is due to other organisms than the colon bacillus. Some prefer lactose bile. Others make confirmatory tests on all gas-bearing tubes. These confirmatory tests vary widely. They may consist in making simple streaks on litmus lactose agar or on Endo's fuchsine-sulphate medium, or they may extend to cultures in a series of sugar media, motility, Gram's stain and so on.

The new *Standard Methods* have prescribed a method using litmus lactose agar and lactose agar which will undoubtedly come rapidly into use and enable one to know on reading a report whether either of the two discriminating methods of identifying the colon bacillus have been adopted.

The chief business of most of the laboratories listed in the tables is the control of the water supply, but many of them further justify their existence by making examinations of other substances. Where time permits or sufficient assistance is provided, the chemicals used in the water purification may be made, as well as the coal, oils and so on. Purchases of these substances under the usual guarantees may be enforced, often at a considerable saving.

In city work, food and drug inspection, the milk supply and its inspection, the examination of cement, paving materials, and all city supplies may be put under the control of the laboratory chief.

Where the laboratory men are trained in that line of work, the city laboratory may make the examinations of the board of health's routine. These include specimens of blood for diagnosis of typhoid, sputum for tuberculosis, throat cultures for diphtheria and so on. Some of the last may be reported from ten to twenty-four hours sooner than the state laboratory could report, and a difference of this much time sometimes means saving a life.

The author has merely mentioned these possibilities of the extension of the scope of the laboratory to show how it can be made to serve the community in other fields. We, of course, should maintain that the first duty of the water laboratory is to maintain an economical treatment of the water supply which will insure a safe water at all times.

In the consideration of table 2 it is hard to draw general conclusions other than that most of the plants are operating efficiently. All do not treat the same sort of water by any means. The variation in turbidity, color, alkalinity and bacterial content of the raw water is very great. The turbidities range up to 12,000, the color to 480 and the alkalinity from -90 to $+580$. The maximum body temperature count of bacteria on the raw water is 210,000; the maximum of the 20° count is 1,000,000 organisms per cubic centimeter.

In going over the tables of chemicals used, the variation in the necessary doses is clear. The short summary of the figures on the next page is self-explanatory.

TABLE 4

	MAXIMUM IN POUNDS PER MILLION GALLONS	AVERAGE OF MAXIMUM FIGURES, POUNDS PER MILLION GALLONS
Aluminum sulphate	1275.0	334.5
Iron sulphate	850.0	349.0
Lime	3800.0	915.0
Hydrated lime	852.0	316.0
Calcium hypochlorite	20.0	9.5
Chlorine	6.5	3.2

Other factors of special interest are the sedimentation period and the storage period of the treated waters. For most of the rapid sand plants the coagulation period is less than six hours. About one-fourth of these plants have a storage of treated water of less than one hour—a condition which may often lead to difficulties in case of fire. The maximum storage of filtered water reported is as great as ten days, but the average is about six hours. The generally adopted rate of operation is 125,000,000 gallons per acre per day.

In conclusion, it should be remarked that the practice in the plants which are listed, is changing from day to day. In the time that the author has been collecting and tabulating these data, it is inevitable that some alterations have been made. The author has endeavored to make the tabulations as accurate as possible and he believes that they actually represent conditions in the water works industry up to the middle of 1917.

RECOVERING A PUMP LOST IN A DEEP WELL[1]

By W. A. Judd

Well no. 9 at Mason City starts with a 19-inch hole which continues for 225 feet. At that point the diameter is reduced to 16 inches and at 540 feet it is again reduced to 12 inches. The well is 1200 feet deep. In this well is installed a five-stage 17-inch American deep-well motor-driven turbine. The turbine proper is about 90 feet below the well curb and below the turbine are two lengths of 9-inch suction pipe. Water normally stands in the well about 85 feet below the curb and pumps down about 7 feet when yielding 1200 gallons per minute.

The construction of this type of pump and its connections are well known. The weight of the pump is carried by the 10-inch flanged discharge pipe in 8-foot lengths. Inside this discharge pipe is another pipe, 4 inches in outside diameter, held in position by spiders inserted in the flanges of the discharge pipe. This pipe is connected together by screw couplings which also serve to hold the shaft bearings. Inside this pipe is the shaft.

The pump is overhauled each year. On New Year's day, 1917, the pump had been lowered together with four lengths of discharge pipe, shaft casing and shafting. The fifth length of shafting had been screwed up tight and the fifth shaft casing was being set up solid when, without any warning, casing and shaft disappeared through the discharge pipe and with the pump and two lengths of discharge pipe went bubbling down to find a resting place on the ledge 225 feet below the surface. The two remaining lengths of discharge pipe were pulled out and it was found that in making up the shaft casing joint, the discharge pipe had worked loose from the flange.

A well driller's advice was immediately sought, and he recommended trying to couple on to the shafting, which projects about a foot above the bearings. One of the shaft couplings was taken to a machine shop and the threads recut to make a loose fit. One end was tapered out on the inside and the other end was cut down to

[1] Read before the Iowa Section, October 10, 1917.

take a 2-inch pipe coupling. On the bottom was soldered a heavy funnel to center the coupling over the shaft. Two-inch pipe was then cut into about 10-feet lengths for ease in handling and threaded. Because the shafting has a left-hand thread, it was necessary to drill each pipe coupling after the joint was made up and pin the pipe and coupling together. This was a tedious process, but finally the funnel was heard to strike the shaft. It was then raised and lowered a few times to be sure of centering and the men began to twist the pipe to the left. After several attempts, it seemed to take hold and hoisting was attempted with an 8-ton chain hoist which hangs from a trolley running on a 15-inch I-beam near the roof of the pump house. From the hard pull, it was known that the coupling caught hold of the shaft, but at about the third pull on the chain, the coupling became loose and for a day the men fished continuously without getting another nibble. The string of pipe was then pulled out and it was found that the funnel had bent over, allowing the shaft to center in the funnel to one side of the coupling. A heavier funnel was built, reinforced with steel ribs and bands, but even with this there was no luck, the shaft turning every time the threads engaged.

During this time one of the men had been telling of a fishing tool he had heard of, consisting of two rings. Just how the rings were operated no one knew until the blacksmith started to make such a tool. The small end of the funnel was cut off so the hole through it was about 5 inches in diameter. A fork was made to which the funnel was riveted. Above the fork was welded a piece of 2-inch shafting 3 feet long in such a way that when the shaft and funnel were vertical, the face of the steel was about 2½ inches from a vertical line drawn through the center of the funnel. On the back of this bar, two ears were welded and punched for a 1-inch bolt. Two open rings were made, 5 inches in diameter, of ¾ inch square steel with the ends bent back, flattened out and punched for a 1-inch bolt. The top of the bar had a piece of 2-inch pipe welded to it, the rings were bolted to their places and wired together so they would move together on the bolts and a light wire was fastened to the top ring to hold them in a horizontal position.

The whole apparatus was then lowered into the well with the same 2-inch pipe, the wire being paid out as the tool descended. The funnel centered the tool over the shaft casing all right, but when the rings were dropped by slacking on the wire, they did not bite into the casing enough to stand a pull so the tool was again pulled out,

a tool-steel face put on the rings, and then notched. A piece of flat tool steel was welded to the face of the vertical bar, and in it were cut some teeth, making it look like a wood rasp. The tool was again lowered and caught hold of the shaft casing with a grip that scarcely anything could disengage. At the first pull it was evident that the pump was wedged tightly into the well, for instead of the pump rising, the I-beam above was bending. Men were sent for props to put under the beam, but while they were gone, the tension on the hoist suddenly slackened, showing that the pump was loose in the well and pulling was started. After pulling continuously for several hours the pump was landed on blocking on the well curb and those who had been fairly on needles for a week went home and to sleep undisturbed by dreams of a big fire and no water.

PRICES AND DEPRECIATION OF CAST IRON PIPE[1]

By Burt B. Hodgman

The history of the prices of cast iron pipe, showing the changes in price during the past fifty years or more, is particularly interesting at this time. Some of the data presented are confusing in one respect, because it is not known whether the prices paid were for pipe by the ton of 2240 or 2000 pounds.

The author has compiled table 1 showing the prices paid for cast iron pipe by the city of Boston, Mass., from 1868 to 1917. This is based on the cost of 6-inch pipe during that entire period and it is interesting to note that the present prices are not as high as the maximum prices paid during the period covered. The prices are based on the long ton from 1868 to 1896 and on the short ton from 1896 to 1917 inclusive. In 1868 Boston paid $78 per ton for 6-inch pipe. In 1873 they paid $67, while in 1897 it was purchased for $16.20 per ton, and this year the price is again up to $45 per ton.

In 1832, 10-inch pipe was purchased by the City of Richmond, Va., from Samuel and Thos. S. Richards of Philadelphia for $1.38 per foot, the pipe being in 9-foot lengths and $\frac{9}{16}$ in thickness. This amounts to about $54 per ton of 2000 pounds; the price was for pipe delivered at Richmond. The prices paid per foot were: 3-inch, $0.37; 4-inch, $0.45; 6-inch, $0.70; 8-inch, $1.25. In 1844, 3-inch pipe was bought for $0.30 per foot and in 1854 16- and 8-inch pipe was purchased from R. and S. H. Jones at $52.50 per long ton. The pipe was cast at Florence, N. J. In 1832, 10-inch valves were purchased in Richmond at $70, 8-inch valves at $56, 6-inch valves at $44.50, 4-inch valves at $30, and 3-inch valves at $28.

It is the belief of the author, after considerable experience in examining cast iron water mains that have been in service all the way up to one hundred years and under almost every condition known in the United States, that the leading cause of depreciation is the corrosion, sedimentation or incrustation which occurs on the interior of water mains.

[1] Read before the Richmond Convention, May 9, 1917.

TABLE 1

*Cost of 6-inch cast iron pipe at Boston, Mass.**

YEAR	PRICE PAID	FROM WHOM PURCHASED
1868	$78.40	R. D. Wood & Company
1870	52.00	S. Fulton & Company
1871	57.50	J. W. Starr
1873	67.20	Gloucester Iron Works
1874	51.00	R. D. Wood & Company
1875	42.00	J. W. Starr
1876	35.00	J. W. Starr
1877	30.00	J. W. Starr
1878	26.47	Warren Foundry & Machine Works
1879	25.20	McNeal Pipe & Foundry Company
1880	42.00	J. W. Starr
1881	31.90	McNeal Pipe & Foundry Company
1882	39.00	Camden Iron Works
1883	36.80	R. D. Wood & Company
1884	34.75	Donaldson & Thomas
1885	29.19	McNeal Pipe & Foundry Company
1886	29.40	R. D. Wood & Company
1887	33.09	Gloucester Iron Works
1888	28.45	McNeal Pipe & Foundry Company
1889	28.31	Gloucester Iron Works
1890	30.34	R. D. Wood & Company
1891	27.95	R. D. Wood & Company
1892	25.40	Radford Pipe & Iron Co.
1893	25.94	R. D. Wood & Company
1894	22.45	McNeal Pipe & Foundry Company
1895	21.60	R. D. Wood & Company
1896	20.25	R. D. Wood & Company
1897	17.17	McNeal Pipe & Foundry Company
1898	16.75	Warren Foundry & Machine Company
1899	16.70	Warran Foundry & Machine Company
1900	26.00	Warren Foundry & Machine Company
1901	20.40	U. S. Cast Iron Pipe & Foundry Company
1902	26.45	U. S. Cast Iron Pipe & Foundry Company
1903	29.70	U. S. Cast Iron Pipe & Foundry Company
1904	22.30	U. S. Cast Iron Pipe & Foundry Company
1905	26.20	U. S. Cast Iron Pipe & Foundry Company
1906	30.70	U. S. Cast Iron Pipe & Foundry Company
1907	35.00	U. S. Cast Iron Pipe & Foundry Company
1908	24.50	Warren Foundry & Machine Company

* The long ton was used until the 1895 contract with the McNeal Pipe & Foundry Company, when the short ton came into use. Prices furnished by C. J. Carven, Engineer of Water and Sewer Division, Department of Public Works, Boston.

TABLE 1—*Continued*

YEAR	PRICE PAID	FROM WHOM PURCHASED
1909	23.30	Florence Iron Works
1910	24.60	Florence Iron Works
1911	20.70	U. S. Cast Iron Pipe & Foundry Company
1912	20.95	U. S. Cast Iron Pipe & Foundry Company
1913	23.60	U. S. Cast Iron Pipe & Foundry Company
1913	20.85	U. S. Cast Iron Pipe & Foundry Company
1914	21.10	Florence Iron Works
1915	20.95	Standard Cast Iron Pipe & Foundry Company
1916	29.24	R. D. Wood & Company
1917	45.50	R. D. Wood & Company

About two years ago questions were sent to water works superintendents and engineers all over the United States, asking for their experience with various kinds of water mains. Answers were received covering users of more than 15,000 miles of cast iron pipe and are summarized in Table 2. These answers came from nearly every State in the Union and almost without exception the answers stated that the outside surface of the iron was in excellent condition. There were some exceptions, but where those exceptions occurred there was some special condition covering them. This of course does not cover the subject of electrolysis, but that should be considered a special condition, the same as the pitting on the outside which occurs in cast iron mains laid in peat bogs or in cinders.

Incrustation or scale results from several different causes. Probably the principal is iron corrosion due to soft waters which are likely to contain free carbonic acid, crenothrix, or some kindred source of trouble, such as manganese, sulphur, organic or mineral acids, all of which will greatly accelerate the incrustation of these mains. Also it should be noted that greater corrosion takes place in pipes which have free iron exposed, as is the case where the line is frequently tapped. This may be due to galvanic action. It is, nevertheless, a fact that the same water passing through a tar-coated line which has not been tapped will affect that pipe less rapidly than where corporation cocks have been placed at frequent intervals.

There are other incrustants, such as pipe, sponge, pipe moss, etc., but it is not the author's object to discuss them from a chemist's standpoint, as this was very thoroughly covered by N. S. Hill, Jr., in a paper read before this Association in 1907.

TABLE 2

Summary of answers to questions on condition of underground water mains

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
New London, Conn....	70	43	Cast iron; fair; 20 miles wrought iron removed because of improper coating
Steubenville, Ohio.....	30	70	Tuberculated; good after fifty years; small pipes abandoned because of corrosion
Boston, Mass..........	826	66	Corrosion ½ to 1 inch; some abandoned on account of salt marsh fill
Elgin, Ill..............	70	27	Good as when laid
Champaign, Ill........		30	Good. No pitting inside or out
Philadelphia, Pa.......	1800	94	Iron corrosion inside;—outside good
Waltham, Mass........	54	25	Excellent condition; no pitting inside or out
Spokane, Wash........	359	30	Steel; thirty years; good. Cast iron, good. Wood, 12 years. Cast iron and steel about same. Wood bands gone, wood rotten
Rochester, N. Y.......	420	41	Good
Las Vegas, N. Y.......	23	35	Cast iron slightly rusted outside due to alkali soil. Steel and wrought iron rusted out
Omaha, Neb...........	297	35	Electrolysis in 1200 feet; 6 inch
Peru, Ind..............	35	41	Excellent inside and outside
Bangor, Me............	55	38	Excellent inside and outside
Cincinnati, Ohio.......	714	70	Cast iron incrusted inside; outside fair
Pawtucket, R. I.......	192	38	Replaced with larger size; slightly tuberculated; outside good
Keene, N. H...........	47	39	Replaced by larger size. Cast iron good. Wrought iron poor, cement lined on account of breaks
Hudson, N. Y.........	30	42	Some pittings on outside. Wood and cement-lined replaced because not strong enough
Kalamazoo, Mich......	90	45	Good inside and outside
Fort Wayne, Ind.......	140	32	Good inside and outside except pitting in cinder fill and some electrolysis
Memphis, Tenn........	265	40	Good
Buffalo, N. Y..........	580	65	Good
New Britain, Conn.....	90	35	Some pitting in inside smaller mains. Outside pitting in cinders. Cement lines abandoned
Meadville, Pa..........	35	40	Good. Some pitting in cinder fill
Streator, Ill...........	47	28	Good, Some electrolysis

TABLE 2—*Continued*

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
		years	
Lancaster, Pa.	71	79	Good
Danvers, Mass.	60	20	Cement-lined, laid in 1876 given out, especially in smaller sizes. Cast iron tuberculated inside
Peekskill, N. Y.		40	Good
Davenport, Iowa	94	41	Good
Marshalltown, Iowa	40	40	Good
Hartford, Conn.	183	60	Good. Cement-lined failed and replaced with cast iron
Milwaukee, Wis.	517	43	Good as new after forty years
Detroit, Mich.	917	60	Good
Schenectady, N. Y.	113	30	Good
Marquette, Mich.	26	44	Slight incrustation inside, outside clean and bright
Montgomery, Ala.	105	35	Good inside and outside
Fort Wayne, Ind.	46	28	Excellent
Galveston, Texas	73	29	Good
Washington, D. C.	591	57	Inside tuberculated. Outside good, except in ash fill and some of the old horizontal-cast pipes replaced.
Ogdensburg, N. Y.	30	25	Some cement-lined pipe forty-six years old, still in use. Cast iron good except where laid in peat bogs
Lafayette, Ind.	56	39	Perfectly good inside and out
St. Louis, Mo.	975	50	Some tuberculation inside. Pitting outside in some places where there is damp yellow clay
Evansville, Ind.	120	42	Tuberculation inside but no pitting inside or outside
New Orleans, La.	570	5	Good
Stockton, Cal.	40	35	Good. Adobe soil affects outside some
San Jose, Cal.	160	47	Inside good, outside some pitted due to alkali soil
Seattle, Wash.	584	35	Cast iron good. Kalamein good. Some wood and spiral-weld pipe removed
Madison, Wis.	86	30	Good inside and outside, except in marshy soil filled with ashes and rubbish; 1000 feet replaced account of electrolysis
Holland, Mich.	29	19	Good
Middletown, Conn.	38	32	Inside tuberculated. Outside clean. Cement-lined replaced

TABLE 2—*Concluded*

PLACE	MILES	AGE OF OLDEST PIPE	CONDITION
		years	
Newburgh, N. Y.	48	61	Tuberculated inside, outside good
Battle Creek, Mich.	73	28	Inside good; outside good, except few places where laid in swampy clay; 2000 feet 6 inch wood pipe in use still, laid 30 years
Cumberland, Md.	40	30	Inside fair, outside good
Dubuque, Iowa	57	55	Cast iron, good
Quincy Ill.	72	40	Cast iron, good inside and out
Johnstown, Pa.	113	48	Good; some outside pitting due to acid soil
Charleston, S. C.			Good
Bridgeport, Conn.	220	35	Tuberculated inside. Outside good. Some electrolysis.
Providence, R. I.	415	45	Some tuberculation. Outside good except in heavy damp soils
Portland, Ore.	543	60	Cast iron good. Some pitting in steel pipe. Some wrought iron and wood abandoned.
Cambridge, Mass.	138	58	Inside tuberculated. Outside good, some electrolysis. Cement-lined removed
Poughkeepsie, N. Y.	44	43	Good except where laid in ashes
Atlanta, Ga.	353	38	Inside tuberculated. Good except in isolated places
Council Bluffs, Iowa	60	33	Cast iron incrusted inside, good outside
Terre Haute, Ind.	96	42	Cast iron, good inside and out; 24 feet removed, electrolysis
Lowell, Mass.	150	40	Good as new

Besides the iron corrosion, various deposits are found in mains which are due either to sedimentation or the settling of lime in the water after treatment for softening or the deposit of limestone, such as is found in Salt Lake City, Utah, or the deposit of mud, or the deposit of red mud due to the presence of free iron in some waters, particularly ground waters. These deposits take place in many different forms. The red mud deposits all around the pipe in a wavy surface which retards the flow very much. Then there is a clay deposit, such as that found from the Big Muddy River in southern Illinois, where the clay mud deposits all around the pipe concentrically, in one case to the extent of cutting down an 8-inch pipe

to an open area of 5 inches. The surface of this also was wavy, further reducing the carrying capacity of that pipe. Then there are the waters which deposit mud in the bottom of the pipe, sometimes filling mains to more than one-half their diameter. This form of sedimentation is found in almost every part of the United States where turbid waters are pumped.

The results of a number of tests are submitted herewith, Table 3, showing the approximate number of years pipes in various localities have been down, the kinds of water passing through them and the percentage of carrying capacity lost on account of this corrosion. These tests, while not numerous enough to form the basis for definite conclusions, may perhaps be of use to the superintendent in determining what his conditions and his troubles may come from. Many tables of the flow of water in cast iron pipes give a coefficient to use for pipe a certain number of years old. These coefficients are so variable that it seems better to find out what the local conditions are for each particular place before deciding what a pipe will carry after being a certain number of years in service. Some comparatively hard waters, such as that of the Great Lakes, for instance, may flow through cast iron pipe for twenty years without seriously affecting the carrying capacity, while the waters of the Ohio River almost invariably reduce the carrying capacity to a very large extent in that length of time. In New England the surface waters in general will probably reduce the carrying capacity of small mains from 25 to 40 per cent in twenty years. Some of the snow waters of the Pacific Coast have reduced the carrying capacity of cast iron pipe to the extent of 50 per cent in twenty years. Some of the Southern surface waters which are very soft and in some cases contain organic acids have been known to reduce by 75 to 80 per cent the carrying capacity of small mains in a period of twenty years. The upper Mississippi, which at times runs very high in hardness seems to affect pipe but very slightly, except where the water has been softened, thereby causing a heavy rough deposit of lime. This is more or less true also of the Missouri River or Central Plains waters. Then there is the Arkansas River water, which runs very high in salt as well as alkalinity, and in the small pipes carrying this water there is frequently a reduction of 50 to 60 per cent in the carrying capacity in a period of twenty years.

To give the superintendent an idea of the effect of corrosion on 6-

TABLE 3

Loss in capacity of cast-iron pipe

LOCALITY	KIND OF WATER	SIZE	AGE OF PIPE	CAPACITY LOST	SPECIAL CONDITIONS
		inches	*years*	*per cent*	
South Milwaukee, Wis.	Lake Michigan	10	15	18	Hardness, 180–200
Chicago, Ill.	Lake Michigan	6	30	32	Hardness, 180–200
Rochester, N. Y.	Lake fed by springs	4	25	25	Spring water
New Jersey	Ground	6	30	34	Iron deposit
Missouri	Mississippi and Missouri Rivers	20	21	50	Lime and iron treatment
Rochester, N. Y.	Genesee River	12	28	52	Surface water
Lockport, N. Y.	Erie Canal	6	20	54	Polluted with sewage
Salt Lake City, Utah	Mountain water	6, 16	20–25	50–65	Hardness very high
Camden, N. J.	Ground water	8	55	60	
Philadelphia, Pa.	Surface water	6	70	56	Hardness, 180
Cumberland, Md.	Potomac River	6	26	50	Hardness, 100–120
California	Mountain snows	16	18	50	Very soft
Meridian, Miss.	Surface and spring	16		50	Soft, sometimes acid
Madison, Ind.	Ohio River	6	25	60	Soft and sediment
New York	Surface water		31	70	Soft water
Kansas	Missouri River	10	28	62	Treated with lime; hardness, 300–450
Kansas	Missouri River	24	21	44	
Mt. Vernon, Ill.	Surface water	6	18	75	Manganese present
Arkansas	Arkansas River	6	20	78	High in salt and hardness
Missouri	Ground water	4	20	80	Sulphur and other minerals
Philadelphia, Pa.	Surface water	6	70	56	Hardness, 180

Huntington, W. Va.	Ohio River	6	20	75	Soft; mineral acids
Wheeling, W. Va.	Ohio River	6	20	80	Soft; mineral acids
Illinois	Surface water	6	31	70	Soft water
Long Island	Ground water	12	50	80	Soft
Boston, Mass.	Surface water	16	59	47	Soft water
St. Louis, Mo.	River water	6	25	63	Treated water
Meriden, Conn.	Surface water	12		49	Soft
Connecticut	Surface water	36	25	32	Soft

NOTE: The percentage of carrying capacity lost in large pipes is not as great as that in small pipes, due principally to the fact the percentage of area filled by corrosion in the large pipes is not as great as that in the small pipes.

to 12-inch mains, so that he may judge of his local conditions by noting the interior of his mains when cuts are made, the following estimates are made:

Tubercules from $\frac{1}{8}$ to $\frac{1}{4}$ inch in depth, occurring principally at the bottom of the interior surface of the pipe, will cut the carrying capacity from 15 to 20 per cent,

Tubercules from $\frac{1}{8}$ to $\frac{3}{8}$ inch in depth, covering practically the entire inner surface of the pipe, will cut the carrying capacity from 35 to 40 per cent.

Tubercules from $\frac{1}{4}$ to $\frac{1}{2}$ inch in depth, covering the entire inner surface of the pipe, will cut the carrying capacity from 45 to 50 per cent.

Tubercules from $\frac{1}{2}$ to 1 inch in depth all around the inner surface of the pipe will cut the carrying capacity down from 70 to 75 per cent.

To determine the effect of this corrosion on the pipe some 25 samples altogether have been analyzed to ascertain the exact amount of the iron from the pipe which has been destroyed. In the worst samples, the rate of destruction is only about 0.1 per cent per year, or 10 per cent of the iron in 100 years. In some isolated cases, underneath these tubercules, there is a slight pitting, but even though the pipes are scraped, some scale is left covering this pitting and forms more or less of a protective coating to the iron at that point. As a very large factor of safety is used in designing cast iron pipe this pitting could be many times as bad as it has been in any place so far observed without seriously endangering the strength of the pipe. Many have seen samples of old Scotch pipe which was cast on its side, which had less than $\frac{1}{8}$ inch of metal, and this thin metal has stood the test of fifty and sixty years service. An example was found in Boston where there was only about $\frac{1}{16}$ inch of metal, and a very light tap with a chisel broke into the pipe. This pipe had been in service more than fifty years and there had never been a break in the line. Cast iron pipe has been in use in France for nearly two hundred and fifty years. Samples of pipe in Philadelphia, in service ninety-eight years, show an excellent condition of the metal, even though an analysis indicates the presence in the iron of elements and compounds that the present-day foundry would not have in a piece of its pipe.

DISCUSSION

A. F. Kirstein: The speaker has adopted the plan, when making repairs, of backfilling the lower half of the trench with soft mud and the upper half with ashes. Has the author any information to show whether this will injure the pipe?

J. N. Chester: In western Pennsylvania there is considerable slag and refuse from coal mines in the ground at places. Whether a pipe laid as Mr. Kirstein describes will be injured will depend upon whether the leaching from the cinders reaches the pipe, or whether the cinders themselves will do as much harm as the leaching. If acid is formed from the cinders and reaches the pipe, damage is bound to be done.

With regard to the author's statement that tuberculation is about the only depreciation that need be counted on in cast-iron pipe protected from cinders and electrolysis, tuberculation will vary with the kind and quality of water that the pipes carry. Some who have used lime and iron as coagulant have found that they depreciated pipes very rapidly. When hypochlorite is used in water without filtration its effects will be apparent in the tuberculation of the pipe. Acid waters in mining districts act as tuberculators, and all know the effect of turbid waters. The use of lime and iron as a means of precipitating the turbidity of our western river waters without filtration may cause severe tuberculation. With filtration there is no harmful effect.

The speaker's experience is that small pipe tuberculates much faster than larger pipe. It was attributed for a while to the velocity, but at Little Rock, Ark., where a 4-inch pipe was run around from a 16-inch pipe and back into it, the 16-inch pipe being a discharge main, there was no reason to believe that the same velocity was not maintained in each pipe, and yet the 4-inch pipe was almost stopped up by tuberculation, and the 16-inch was hardly tuberculated at all. Observations subsequent to that time, which was twelve years ago. indicate that almost without exception a 4-inch pipe will show far greater tuberculation than a 16-inch. Ordinarily large lines are through lines, and naturally have higher velocities because they are not subject to dead ends; they are carrying water to the smaller mains, and velocities are generally higher in the larger than in the smaller mains.

George A. Main: The speaker will be interested to know the author's estimate of the proportion of the frictional loss due to the increased velocity made necessary by the reduced cross-section, and the proportion of the frictional loss due to the tuberculation.

With regard to the greater tuberculation and precipitation in small pipes as compared with large pipes, the speaker has found that there will be more lime precipitated from the softened water of Daytona in a $\frac{5}{8}$-inch goose neck than in the $\frac{3}{4}$-inch pipe forming part of the same service, although both carry the same amount of wate . The following explanation of this, and of the greater precipitation in small than in large pipes is offered: The eddy currents produced near the surface of the small pipes bring practically all particles of water into contact with the surface of the pipe. In the larger mains, the eddy currents are probably smaller in proportion to the diameter of the pipe, and therefore considerable water flowing near the axis of the pipe would come in contact with the metal much less frequently than in a small pipe. With a given velocity of flow there would be much more precipitation where all the water has a chance to reach the surface of the pipe.

Rudolph Hering: The effect of the roughness of the surface of a conduit on the flow of water through it was well shown by some of the celebrated experiments of Darcy and Bazin. One of their tests concerned two lines, each several hundred feet long, with semi-circular channels 1 meter in diameter. One was lined with rough rubble masonry; the other was lined with cement made perfectly smooth. They found that the quantity of water passing through the smooth cement-lined channel of the same sectional area and scope was just about twice that which went through the channel having the rough rubble surface. The 50 per cent loss was due to nothing else but the increased roughness.

Has not the quality of the material more to do with this question of tuberculation and roughness than the size of the pipe? The speaker recalls some celebrated experiments made years ago in the Whortley Iron Works, near Edinburgh, Scotland, by Andrews, who found that the quality of the material had a great deal to do with the tuberculation, caused by the formation of a battery, as it were, by pure iron, uncombined carbon, and the acid character of the water. The slightly acidulated water caused the electrical action. Those experiments, published in England about thirty years ago,

very clearly indicated that the presence of uncombined carbon in wrought and cast iron was the chief cause of rust. Therefore, in San Francisco, the engineer of the Spring Valley Water Company, Mr. Schussler, desiring to use iron pipe at a time when it was very expensive to get iron pipe on the Pacific Coast, thought that he might use wrought-iron for his pipe; and as he had in mind the experiments made at the Whortley Iron Works, his specifications called for iron from which the uncombined carbon had been almost entirely removed by repeated rolling. The speaker saw some of those pipes after some years' use, and he was surprised at their condition. There was hardly any rust on the surface after many months' exposure to air and rain. Therefore he thinks the uncombined carbon that is generally found in cast-iron may have a good deal to do with the tuberculation of iron pipes.

Charles F. Barrett: On 1915, an examination of a number of water mains in Salt Lake City showed that they were carrying only 36 to 65 per cent of the quantity of water they should deliver. They were then cleaned and the discharge through them tested. These tests showed that the average discharging capacity of the cleaned mains was about 99 per cent of the theoretical capacity. An analysis by the state chemist of the scale removed by the cleaning operations showed that it was composed of 90 per cent of calcium carbonate, 5 per cent of silica, 3 per cent of iron and alumina, and 2 per cent of magnesia.

E. E. Davis: The speaker has taken up a great deal of pipe laid in the forties, and found it the worst pipe he ever had experience with. He has taken up 4-inch pipe that showed what were then called "rust bubbles" but are now called "tubercles." An old waterworks man told the speaker that this badly tuberculated pipe laid in the forties was made at blast furnaces and not in foundries; in other words, they did not run the iron into pigs but the pipes were cast at the furnace. In those days the makers did not have to conform to any specification as to quality. There was some old pipe in which it was impossible to cut a hole with a diamond, yet it became tuberculated.

In Richmond not much trouble is experienced with anything except James River mud. Since sulphate of alumina has been used as a coagulant, instead of the mud inside the pipes becoming very hard

it has a consistency like that of vaseline. Formerly when there was a fire it was difficult to obtain a good stream out of a pipe because of that mud, until the hydrant was allowed to flow for a while and the mud was flushed out.

LEONARD METCALF: The discussion might be directed to one or two points of importance in their bearing upon valuation of water works.

First, you are urged to do everything that you can to keep your records clear and to keep good records of the actual cost of your work as you go along. That is coming to be a matter of greater importance in valuation and rating problems as time goes on. As an example of the effect of information of that sort, there may be cited the recent valuation of the Indianapolis Water Company, the rates of which were under question. The cast-iron pipe records were in very fair shape from the earliest days of the company down to date. The greater part of the purchases had been made in the last twenty years, so that they had a far greater influence on total cost of pipe than the earlier purchases, though the earlier purchases had been at much higher rates; but after a study of the cost of the pipe and actual purchases by that company, and by other companies in that vicinity, it was concluded that the ten-year average was approximately $24 per ton of 2000 pounds; that the five-year average was approximately $1.50 per ton less than that amount; but that the actual cost of all the pipe purchased in the life history of the plant was approximately $25.90 per ton. Therefore, it was suggested to the Commission that in all fairness to the company and justice to the community, the five-year average which had sometimes been used in such cases was not a fair one to use, nor did the ten-year average in this case do full justice to the facts, particularly as an era or a period of high prices is here. Inasmuch as there could be no doubt that the average price for the succeeding or coming ten years will doubtless be higher than for the past ten years, it would certainly be fairer to use a figure more nearly approaching, if it did not equal, the actual cost of the pipe to the company. Therefore, in this case the importance of the record to the company is clear.

It is also of importance to know the exact source of data. It has been very common to use quotations from trade journals; if no better information is available, these may be of value, but if the records of actual prices paid within the decades covered by the records are compared with these quotations, considerable divergencies will ap-

pear even though a comparison of the prices paid by neighboring cities for the pipe show fairly consistent and similar results. The statement which one sometimes hears, that pipe is not bought in the years of high prices and that therefore less weight should attach to the years of high prices than to the years of low prices, is not borne out by the history of existing plants generally. A study of such records shows cases of which that can be said, and many cases of which it cannot be said. The speaker does not feel that the data which he has, though they cover the experience o a number of works, are broad enough to determine the average condition. In comparing the prices of pipes bought by seven or eight cities, as many cities were found to have bought pipe at the higher prices as had bought it at the generally lower prices, which simply illustrates what all know, that when the need is urgent mains must be laid regardless of the price of pipe.

With regard to the carrying capacity of mains, it is frequently found, particularly with waters carrying more, rather than less, organic matter, that a pipe line in proximity to reservoirs will show greater frictional loss or resistance, particularly when the source of supply is from a river or lake, than elsewhere in the pipe system, owing to incrusting organic material and slime or sponge. The speaker has seen sponges one-half of a square foot in area and 2 or 3 inches in length in some penstocks and pipe lines and living aquaria inside of these pipe lines in proximity to the reservoirs or sources of supply.

The progressive deterioration in any good pipe line is difficult to determine from inspection or measurement. The most accurate and helpful way to determine it is to make experiments and keep records of the increasing frictional resistance to flow in the pipe line from year to year. The speaker had a very interesting experience a few years ago in going through a number of wrought-iron and steel pipe lines. Among them was a pipe of the New Bedford Water Works, inspected with Thaddeus Merriman, of the New York board of water supply, who had been through this same pipe and taken micrometer measurements of the pitting about five years before. It was hoped to obtain suggestive ideas from that comparative experience; and quite a large number of measurements of the length of the tubercles and blisters and pitting were made. This pipe line was of steel and not of cast-iron; but the same thing might be said of a cast-iron pipe line. The pipe line was entered at a number of points and traversed through several hundred feet, in the aggregate, of its

length. Mr. Merriman stated that he could not see that a comparison of his earlier and later records showed any substantial difference; whereas the pumping station records did show some difference.

The Pitometer Company has, in the course of its experience, made some exceedingly interesting studies of pipe lines in this country. The speaker remembers one such, reported at Denver, where the plant was being valued. Some approximate experiments had been made with more or less crude apparatus to determine the friction loss of the lines. The results were higher than expected, and it seemed wise to have more precise measurements made. The Pitometer Company was called upon to assist; and in order to get as useful information as possible, pipe lines of varying ages, varying from a decade or more, were selected and gagings were made in the hope of being able to determine the progressive deterioration in carrying capacity. The data are quite interesting, and will be valuable when placed side by side with other similar records. Of course they cannot be directly applied to any other condition, particularly as it was clear that the waters of that region, perhaps due to their magnesia content, had resulted in a greater roughening of the surface, or sufficient roughening of the surface, to account for the difference in carrying capacity, although this was not always apparent to the eye. Dr. Hering has already called attention to the fact that a very slight apparent difference in the character of the surface may bring about a very marked difference in carrying capacity.

The speaker's experience has been the same as Mr. Chester's, that with pipe of like ages it is found that when the coefficient for the Hazen-Williams formula for a certain age is, let us say, 80 for small pipe, for a large pipe of like age the coefficient will be 90 or 100, or more; in other words, that the same reduction in carrying capacity does not result in the larger pipe, although the apparent interior condition of the pipe does not differ so markedly that the difference can be distinguished by eye.

The speaker has been through hundreds of feet of the Spring Valley Water Company's pipe, in and near San Francisco which was referred to by Dr. Hering, which has made a most remarkable record for itself. The record was due partly to the excellent surface coating developed by Mr. Schussler which has shown remarkable properties after forty-seven years' use. Pipes were traversed that had been down twenty-five or thirty years and the coating was found almost perfect. While it appeared fairly hard it could be dented

with the thumb-nail. Placing the thumb on it and working it gradually from side to side softened the coating enough to flow; yet it has been hard enough to keep its shape. Allen Hazen and the speaker went through 700 feet of another pipe line 44 inches in diameter, and there were only one or two blisters in each length of 3 feet or so, which shows in what a remarkable state of preservation that pipe line is.

With regard to Mr. Davis's statements about the tuberculation of old cast-iron pipe, it is probable that while some part of the improved carrying capacity of recent pipe may be due to better metal and better foundry practice, most of it is to be attributed to the pipe coating. A large part of the old cast-iron pipe was uncoated, and its quality varied greatly.

F. N. Connet: Tuberculation seems to be quite distinct from incrustation and is more apt to occur with soft than with hard waters. In cross-section a true tubercle is built up of a series of thin layers like an onion and the speaker believes that two layers per year are usually deposited. Since the growth of crenothrix also occurs twice a year, the question arises whether the tubercle may not be the remains of successive growths of this organism. The metallic iron underneath the tubercle is usually dissolved out in the shape of an inverted cone leaving the uncombined carbon unaltered and intact, but this latter can be easily cut out with a pen knife.

The speaker has observed the tendency of tubercles to collect near brass fittings, which suggests electrolytic action also. May not the crenothrix, because of its iron content, be deposited electrolytically upon the tubercle, thus causing it to grow indefinitely? In other words, may not a tubercle be in reality a graveyard of many generations of crenothrix?

B. B. Hodgman: In discussing old records of prices of pipe it is important to keep in mind the ton used in each case as the unit of quantity. At Providence, R. I., for instance, pipe was bought by the long ton down to 1905. In comparing prices over a long range of years, the selling price may be found to have been affected at times, in a measure, by the currency conditions, which some persons consider were influential in fixing prices from 1868 to 1873.

Where pipe lines are covered by a foot or more of earth which is covered in turn by cinders, the author has never discovered that water percolating down through such backfilling injured the pipe.

The tuberculation of pipes as actually found during testing and cleaning operations presents many interesting features. For instance, in recent tests of a 24-inch main and a 10-inch main laid at about the same date, the larger pipe was found to be carrying considerably over 50 per cent of its rated capacity when new and the smaller pipe about 40 per cent. In Lockport, N. Y., it was found that the carrying capacity in a 6-inch main in a busy part of the city was only 40 per cent of that of new pipe, but farther along, where there was a much lower velocity through the main, the capacity was 90 per cent of that of new pipe. It has been observed that the number of taps in a main has a decided influence on the deterioration in its carrying capacity. For instance, 2000 feet of 8-inch pipe without taps, tested in New Haven, Conn., showed a much smaller loss of capacity than was found in the next 2000 feet, where there were taps for a house on each side of the street every 50 feet or so. As a rule, it is found that there is more tuberculation in a line with taps than in one without them. The reduction in area by tuberculation is, of course, proportionally greater with small than large pipes. Half an inch of incrustation on the inside of a 4-inch main reduces its area about 45 per cent, whereas half an inch of incrustation on a 16-inch main reduces its area only 7 per cent. It is this decrease in effective area of a pipe which is responsible for a considerable part of the difference in its carrying capacity; the decrease should not be attributed exclusively to increased frictional resistance due to tuberculation.

SOME FEATURES IN ARTESIAN WELL CONSTRUCTION IN MANKATO[1]

By H. F. Blomquist

Mankato is located in the artesian basin of Minnesota, being in the southwestern part of it, and a number of artesian wells have been sunk in the city. The first was sunk in 1888. One of the deepest wells in the United States is located only 1½ miles from here. The hills around Mankato are about 230 feet above the street level and the city wanted a well upon the top of one of these hills, called Bunker Hill, one of the highest in the city. A well was drilled about 2204 feet deep and was at that time one of the deepest, if not the deepest, in this country. The water rose within about 40 feet from the surface. That would bring the water approximately 175 feet above the elevation of the business section of the city. It was intended to run that water into a reservoir but the plan did not work out as well as anticipated. The city spent $12,000 in the experiment but the well has never been used. An artesian well was sunk in this city about two years ago that is 1452 feet deep.

One of the first wells that was drilled was about 365 feet deep. Two others were sunk about 665 feet each and gave the required supply of water. In 1900 one of those wells was deepened to 1365 feet to increase the flow of that well. The flow then was over 600 gallons a minute, flowing at the surface of the ground. That was sufficient until more wells were dug, particularly one by the Hubbard Milling Company. The one deepened to 1365 feet was again deepened last summer to 1450 feet, and given an iron casing to a depth of 220 feet. Steel casing lasts about twelve or fifteen years. It has been necessary to replace the casings of two wells within the last three years. A bad feature is that when the casing starts to leak it is necessary to put in a smaller casing, thereby reducing the size of the well. In the last well that was built, a cast iron casing was used, A 16-inch hole was drilled and a 15-inch pipe was lowered about 90 feet. A 15-inch hole was continued to 156 feet. Cast iron pipe

[1] Abstract of a paper read before the Minnesota Section, November 10, 1917.

was made expressly for this well, threaded at the ends and coupled together with brass couplings, and it is hoped the well will stand about fifty years more.

The water here contains a certain amount of substances that are not wanted and some kind of purification is desirable. There are some peculiarities in the water not found in the ordinary well supplies. The artesian water comes from the depths where the pressure is very high, and since water under high pressure holds substances in solution which would otherwise be in solid form, the water of Mankato contains matter in solution which is afterwards precipitated when the pressure is relieved. Evidence of this is often seen when water is drawn from a faucet into a glass. The water containing carbon dioxide in solution under pressure holds iron and sulphur compounds in solution, which, when the pressure is relieved and the water comes into contact with air, undergo chemical reactions which change the iron compound to ferric hydroxide which precipitates into a brown substance, and is so often seen when water is allowed to run slowly over a light colored surface. The sulphur is given off in the form of hydrogen sulphide, which has the peculiar odor that is responsible for the erroneous assumptions of some consumers that the water has become stagnant in the mains. The carbon dioxide is also given off when the pressure is relieved, and being a gas it forms in small particles and gives to the water a milky or turbid appearance often seen when filling a glass, but which soon passes off leaving the water clear. Because of this quality of the water it is necessary to flush the water mains very often.

THE PROBLEMS OF A SMALL WATER WORKS PLANT FROM THE MANAGER'S STANDPOINT[1]

By T. C. Gordon

The electric power plant and water system at Little Falls, Minn., are both owned and operated by the same company. The power is generated from falls in the river. The two public utilities are housed in the same building and the same men operate both. Water is pumped directly into the main from the Mississippi River, there being no storage reservoir or filtration system, and there are no auxiliary fire pumps.

There are two pumps having a maximum discharge of 2,225,000 gallons and this is taxed during fires of any great extent. The author is not familiar with what other towns of similar size (7000) are doing, but he knows that with the pumps and a fire pressure of 125 pounds it is hard to get a satisfactory pressure a mile or more away from the station. None of the mains are less than 6-inch and in all of the business section they are 8 and 10 inches.

The pumping station is three-quarters of a mile from the business district. When it is necessary to repair the main feeder, all preliminary work is carried out as far as possible before midnight, when the pump pressure is reduced or the pumps shut down entirely if necessary, while the leak is repaired. Repairs to laterals are made behind closed valves, of which there is a liberal supply. There are only three dead ends in the system. Repairs with lead wool were tried but the work was not satisfactory so that lead and oakum were again used. The company does not care to experiment with new ideas if old methods are satisfactory.

In the town the service from the main to the curb is owned by the property owner, but when a leak appears the company is advised that its main is broken and usually has to make the repairs, but only occasionally is it repaid. The company taps its mains and furnishes the corporation cock. As a general thing the sewer and water pipe are laid in the same ditch, the sewer, of course, being much lower than the water service.

[1] Abstract of paper read before the Minnesota Section, November 10, 1917.

All mains are laid 8½ feet below street grade. Frost troubles are confined to services, which are thawed out with electric current using a 10-kilowatt transformer mounted on a wagon with connection to a hydrant and to a service pipe inside the premises. A 50-volt tap on the transformer is used, thereby getting a heavier flow of current. A frozen service is thawed out in less than five minutes. Last winter many services froze which had not frozen in previous years. Fire hydrants are closely watched and steamed out with a portable steamer. Hydrants are inspected after every fire to see that they have drained properly. A great deal of trouble has been experienced with roots plugging up the drain on fire hydrants.

When the system was installed (1890) the contract provided that a supply of pure and wholesome water should be provided taken from the Mississippi River. It was then generally taken for granted and understood that flowing water purified itself in every 15 or 20 miles of travel. The company went along on this theory for several years and must have pumped out of the river millions of germs but without any typhoid outbreak. It installed one of the first hypochlorite plants in the state, much to the disgust of the station operators who had to look after it. As soon as the liquid chlorine method of purification was effected the company tore out the chloride plant and installed the liquid chlorine. From the standpoint of continuity of service the chlorine system is not entirely satisfactory. Parts will get out of order and cause shut-downs, but any shut-down means the pumping of impure water and this of course is something that must be avoided.

An auxiliary pumping plant is to be located within three blocks of the business center. The new unit will be motor-driven with a remote control switch at the present pumping station, and will be used especially for fire protection and in time of trouble at the main plant. It is also planned to install a filtration plant and a standpipe with motor-driven pumps to operate at off-peak periods, These improvements are awaiting an easier market.

ADVANTAGES OF A LOCAL SECTION OF THE AMERICAN WATER WORKS ASSOCIATION[1]

By F. W. Cappelen

The Minnesota section has 34 members and is the smallest of all the sections now formed. By states, including Canada, Minnesota stands eleventh in number of members; 25 of the 34 members reside in Minneapolis, St. Paul and Duluth leaving only 9 members scattered around the state. There is a splendid opportunity for campaigning for members among the small city water works officials in Minnesota. We need the smaller water works men for their good and ours.

Quoting from the speech of President Metcalf at the Richmond convention,

> We should strive to reach and serve the general practitioner, the practically trained man, rather than the highly educated or technical one occupying highly specialized position, to give this large class of capable men the opportunity not only to get together in annual convention, but to assist in developing and advancing the state of art in their particular fields of activity.
>
> The local organizations in any profession or calling have an advantage over those of national membership, in that they afford greater opportunities for personal touch and discussion.

This statement by Mr. Metcalf hits the nail squarely on the head. Have you really considered the tremendous importance of our position, that of furnishing pure, wholesome water for all the people?

Those using chemicals in the purification of water probably know. the difficulties encountered in obtaining such supplies. The author has been obliged to take up the matter of car service for the Minneapolis Water Works with the Board of National Defense. His argument for preferential car service was this: Assume we could not get service and would have to supply impure water to 400,000 people, and cause, may be, a typhoid fever epidemic with a death rate as bad as the war itself, what shall the water department do? This suggestion worked. Minneapolis was assured car service. It can be readily seen how the section can be put to work, and the more members, plant members, we get, the more influence the section will have. There are in Minnesota 271 domestic, and 16 privately owned water plants besides 264 privately owned well supplies.

[1] Read before the Minnesota Section, November 10, 1917; abstract furnished by Section Secretary.

NOTES ON THE PRESUMPTIVE TEST FOR B. COLI[1]

By Max Levine

Examinations of waters for B. coli constitute an important part of the tests employed for the control of water supplies. Isolation and complete identification of the organisms is too laborious and costly for routine work and it is therefore desirable to have some simple test by which the probable presence of B. coli may be quickly determined with a sufficiently high degree of reliability to give a reasonably accurate idea of the existence of pollution.

The ideal medium for such a presumptive test would be one in which B. coli flourishes while other forms are inhibited, but this ideal has not as yet been attained. The requirements of a reliable presumptive test may be briefly stated as follows:

1. The medium employed must be one in which a test characteristic of B. coli is quickly obtained and easily recognized.

2. The medium should not inhibit the growth of B. coli nor permit its overgrowth by such forms as B. aerogenes.

3. Anaerobic spore-forming gas producers should be inhibited or some simple supplementary test provided by which errors due to their presence may be eliminated.

4. It is desirable that the test should also differentiate between true B. coli and B. aerogenes.

Until 1906, the most commonly employed presumptive test was gas production in dextrose broth. The formation of 25 to 70 per cent gas, of which approximately one-third was CO_2 was regarded as an excellent indication of the presence of B. coli and dangerous pollution. This criterion has been conclusively discredited. The variability of the gas ratio as determined in routine analysis, the many bacterial forms which ferment dextrose but not laxtose, coupled with the relatively greater incidence of such forms in treated and partially purified sources than in polluted waters, makes the old dextrose broth presumptive test an unreliable index of pollution. This is particularly true in warm weather.

[1] Read before the Iowa Section on October 10, 1917.

Since 1906 the most commonly employed presumptive test has been lactose peptone bile. The advantages over dextrose broth are many, but recently there has been a tendency to use lactose broth in order to eliminate the inhibitory action of bile.

Where pollution has been recent, the lactose bile or lactose broth presumptive tests are very reliable, but with relatively pure or treated waters, a positive presumptive test is not infrequently obtained when no B. coli are present. This confusion is due to the presence of spore-bearing anaerobic lactose fermenters. The error may be easily eliminated by plating from the positive lactose bile or broth tubes to some solid medium in petri dishes, as recommended by the U. S. Treasury Department Standard for drinking waters on common carriers.

The recent work of Rogers and his associates of the United States Department of Agriculture, which has been confirmed by many other investigators, has demonstrated conclusively that there is a marked correlation between certain types of coli-like bacteria and their sources. Two types may be easily distinguished; the B. coli which is constantly found in feces of man and in sewage but rarely in unpolluted soil, and the B. aerogenes which is rarely obtained from feces, but commonly found in cropped soil, on grains, etc. That these two types are very different in their sanitary significance is evident, since B. coli is characteristically of fecal origin whereas B. aerogenes is not. It is therefore desirable that they be differentiated in routine water analysis.

The following procedure is suggested as routine:

1. Plant portions of the sample in 0.5 per cent lactose peptone broth. Incubate at 37°C. for forty-eight hours.

2. After twenty-four hours incubation smear onto eosine methylene blue agar plates described below, from the highest dilution showing any gas (preferably also from the next highest dilution) and incubate at 37°C. for twenty-four hours.

If gas production is due to B. coli, characteristic black colonies with a metallic lustre will develop on the eosine-methylene blue agar in fifteen to twenty-four hours. B. aerogenes also grows well on this medium but its colonies are so distinctly different from B. coli as to be easily distinguished. Anaerobic spore-forming gas producers will, of course, not develop, thus eliminating the error introduced by their presence in the fermentation tubes.

Lactose broth. The new Standard Methods of Water Analysis of the American Public Health Association recommend 0.5 per cent peptone and 1 per cent lactose for the lactose broth medium, and incubation for forty-eight hours before any confirmatory tests are applied. With 1 per cent lactose, this period of incubation is too prolonged and detrimental to the successful isolation of B. coli. In a private communication Dr. Joseph Race of Ottawa, Canada, points out that beginning with equal quantities of B. coli and B. aerogenes there are found many times as many B. aerogenes as B. coli in 1 per cent lactose peptone bile-salt broth after forty-eight hours. The ratio may be as high as 18 to 1. The probability of obtaining B. coli from such a mixture by plating on litmus lactose agar is evidently slight.

In some unpublished studies in this laboratory it has been observed that with pure cultures of B. coli a maximum count is obtained in about twelve hours. In a medium with 1 per cent lactose B. coli begins to die off after twenty-four hours, some strains disappearing very rapidly whereas many B. aerogenes-like forms do not. If the quantity of lactose is reduced to 0.5 per cent, the death of B. coli is retarded considerably, and the probability of its detection thereby increased. One-half of one per cent lactose is sufficient for rapid and characteristic fermentation and this quantity therefore seems more desirable than the standard 1 per cent.

Eosine methylene blue agar. The agar medium recommended is a modification of that employed by Holt-Harris and Teague for the isolation of B. typhi, and is prepared as follows: Distilled water, 1000 cc.: agar, 15 grams: peptone (Difco), 10 grams: K_2HPO_4, 2 grams.

Boil until dissolved. Make up loss due to evaporation, and place measured quantities in flasks or bottles. Sterilize in autoclave for fifteen minutes at 15 pounds pressure.

Neither adjustment of the reaction nor filtration is necessary.

For use the following materials are added to each 100 cc. of the melted agar as prepared above: 1 gram or 5 cc. of the sterile 20 per cent lactose solution, 2 cc. of 2 per cent aqueous yellowish eosine, and 2 cc. of 0.5 per cent aqueous methylene blue. The aqueous solutions of the dies will keep in the ice box several months.

Differentiation of B. coli and B. aerogenes. On the eosine methylene blue agar as prepared above, B. coli forms characteristic button-like colonies 2 to 4 mm. in diameter with large black centers. There is

also a greenish metallic lustre and they are only slightly raised above the surface of the medium. B. aerogenes forms colonies which are much larger, considerably raised above the surface of the medium: characteristically show a relatively small brown center and the metallic lustre is rarely observed.

Of 122 colonies tentatively diagnosed as B. coli from their appearance on the agar, 97 per cent were B. coli, while of 102 colonies of supposed B. aerogenes 83 per cent were confirmed. The differentiation on this medium therefore seems reasonably reliable.

Conclusions. In the lactose broth presumptive test, 1 per cent lactose is detrimental to the successful isolation of B. coli, as many strains die off rapidly after twenty-four hours. A reduction of the lactose to 0.5 per cent reduces this error and is therefore recommended for routine tests.

For a rapid confirmatory test, the modified eosine methylene blue agar, because of its simplicity, ease of preparation, and the differentiation which it permits between B. coli and B. aerogenes, may advantageously be substituted for litmus lactose agar or the Endo medium, in routine water analysis.

The necessity for confirming the presumptive test and differentiating between the objectionable B. coli and the more widely distributed B. aerogenes and anaerobic gas-formers is not only of theoretical interest but of considerable practical significance when dealing with surface waters which are purified by sedimentation or chlorination. Where the positive presumptive test is due to spore formers, the amount of chlorine necessary to remove them is far in excess of that required to make the water safe. B. aerogenes also seems to be more resistant to treatment than B. coli. A knowledge of the type of bacteria responsible for a positive presumptive test thus becomes of practical significance.

LABOR SAVING MACHINERY[1]

By J. A. Jensen

A change from steam to electrical pumping reduces the number of men required for operation. One motor tender and an assistant replace the firemen, coal passers, boiler cleaners, engineers and oilers required for steam pumping. In filter plants much of the machinery is power operated and automatic, requiring only supervisory attention. Auxiliary electrically driven pumps for booster service are automatically controlled by float switches in the standpipes. They are visited occasionally by the engineer for the purpose of inspection and lubrication.

Labor-saving machinery is required more and more each year because of the growing scarcity of labor. Trenching machines for water pipe laying, auto trucks for transportation and other kinds of machinery for the handling of earth and materials are labor-saving devices.

In 1913 the city of Minneapolis purchased a large trenching machine for use on several miles of trunk pipe lines. This machine put out 39,200 cubic yards of earth at a unit cost of 9.3 cents per cubic yard on about 3 miles of trench. On another piece of work a steam shovel on back-fill handled 23,730 cubic yards on 9250 feet of trench at a unit cost of 4.8 cents per cubic yard.

On work in limestone ledge, trenching for pipe laying, an air compressor and operator with two plug drills and two men replaced twenty men with hand drills. In laying steel pipe the same compressor with ten boiler makers equipped with the necessary riveting and calking hammers, reaming tools and other equipment carried on the work of a whole company of similar skilled labor with hand tools.

A single first-class power operated trench pump has been found to do as much work as three hand-operated pumps manned by a dozen laborers.

[1] Abstract of paper before the Minnesota Section, November 10, 1917.

In service work with miscellaneous jobs scattered over 40 or more square miles of territory, Ford runabout trucks are employed, each rig and two men, generally speaking, replacing three single-horse rigs and six men. This is explained by the fact that the principal part of the performance in street service is mileage, and the work itself is secondary so far as time element is concerned.

METALIUM[1]

By Homer V. Knouse

The industrial progress of the United States has been due not only to the inherent enterprise of Americans, but almost equally to their readiness to put aside old methods and try new processes. This has been true particularly in connection with concentrated industries commanding large capital and corresponding profits. In such cases, under intelligent management, new ideas have been not only welcomed but experimental work encouraged notwithstanding the uncertainty of results and the expense involved, which in many instances has been enormous.

However, there are certain industrial processes that have been unaffected by this spirit of progress, that are utilized today just as they were fifty years, even a hundred or more years ago. Examples are those used here and there in construction work, mostly simple in character and while far from ideal, yet not unsatisfactory. Such processes have thus persisted largely as the result of habit, and the absence of the incentive of material financial gain, which alone seems capable in the industrial world of overcoming the inertia of habit and compelling the adoption of improved methods.

One of these unimproved processes is the use of lead for jointing bell-and-spigot water pipe. This practice was in vogue more than a century ago, and the method remains practically unchanged to this day, even to the use of a mud or clay roll as a joint runner, which still persists in many instances. It is true that lead makes a very satisfactory joint when properly run and calked, but the material and method are far from ideal. First, lead is relatively expensive, hence the loss from oxidation and scattering is material; also being readily saleable, it is subject to theft. Second, for melting, it requires a relatively high degree of heat, often resulting in over-heating and hence oxidation. Third, if not hot enough it cools before the joint is entirely filled, and, in spite of calking, the joint will ulti-

[1] Read before the Iowa Section on October 10, 1917.

mately leak. Fourth, its handling is not without danger because of its weight and the liability of explosion in case of wet joints. Fifth, a lead joint must be calked and the calking should be done by a reliable, skilled mechanic, otherwise a bell may be ruptured, and here and there the bottom of a joint neglected because of the difficulty of getting at it. Skilled calking is constantly growing more expensive, in some localities the wage demanded being as high as 55 cents per hour, with a limit on the number of the joints for a day's work. Unskilled calking means an unsatisfactory job, sooner or later. Sixth, calking requires the digging of bell holes which adds to the cost of excavation. Seventh a leak in a lead joint will persist; it will not decrease automatically but it increases with time.

In view of the shortcomings of the lead joint, the management of the Omaha water plant, some years ago, began seeking a substitute for lead, and as result, experimented with a metalloidal composition or alloy known as metalium. The advantages claimed for this material are the following:

1. Low cost. To compete with metalium as a joint filler lead would have to sell at approximately 2 to 2½ cents per pound.

2. Low melting temperature. This is a little more than one-third that of lead, resulting not only in a saving of fuel but also eliminating all danger from explosion in pouring a wet joint.

3. A relatively high specific heat. This insures with greater certainty the complete filling of a joint, and enables joints to be poured successfully at a considerable distance from the melting pot.

4. A low specific gravity. This is about one-fifth that of lead. Thus a man can easily handle a bucket of molten metalium sufficient to run a 48-inch joint.

5. No calking required. This eliminates the expense of calkers and the digging of bell-holes and also materially expedites the work of installing pipe lines.

6. The automatic closing of leaks developing in metalium joints. Initial leaks gradually close and those due to subsequent settlement of pipe eventually terminate likewise.

After a number of trials, it was concluded that these claims were substantially justified, and metalium has been utilized, to the exclusion of lead, in the installation of all pipe lines within the Metropolitan Water District for the past four years or more. In fact, a carload of lead purchased early in 1913 was subsequently sold at war prices, thereby netting the District a handsome profit.

Joints of all sizes of pipe have been run, from 3 inches to 48 inches in diameter, and during the period in question in the neighborhood of fifty miles of pipe lines have been installed in the Water District, subject to pressures as high as 115 pounds, using metalium alone as the jointing material. In the care of pipe of larger diameters than 24 inches, however, a bestolyte lining is inserted before the metalium is poured.

In view of these facts, it would seem that metalium should supplant lead in the installation of water mains under ordinary conditions, and that too, notwithstanding the inertia of habit, as the saving per mile of pipe in comparison with the use of lead, at 13 cents per pound (the quoted price of lead when these calculations were made) is approximately as follows:

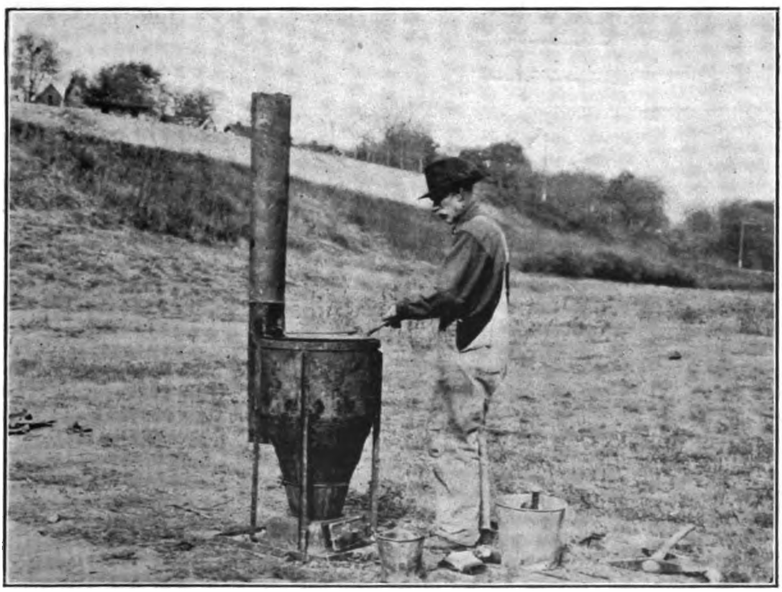
Diameter of pipe, inches.......	6	12	24	48
Saving per mile................	$565	$993	$2415	$5160

While metalium possesses a number of advantages over lead as a jointing material, yet its adoption entails one disadvantage that should be realized and understood by any one contemplating its use. This disadvantage consists in the initial leakage that often takes place in metalium joints when the water is first turned on. In a lead joint, this leakage is obviated by calking, while in the case of a metalium joint, the pressure is left on with the result that calking is accomplished automatically, it being simply a matter of time. This self-calking is not merely an accidental result, experience having demonstrated it to be positive and certain in character.

Although this disadvantage, therefore, is apparent rather than real, it can readily constitute a real obstacle to the adoption of metalium in the mind of one contemplating its use, due to the fear that such initial leaks will not close. However, experience soon dissipates this fear and begets full confidence, so that ultimately there is no hesitation to cover a pipe line as rapidly as joints are run, which is unvarying practice in the Metropolitan Water District.

The following test illustrates this self-calking quality: After a newly laid pipe line was filled, the valves at each end were closed, and the line supplied with water through a $\frac{5}{8}$ inch meter. The first reading indicated a leakage of 1790 gallons per mile in twenty-four hours per inch of diameter of pipe; two days later this leakage was 564 gallons; five days later it was 174 gallons; one day later 139 gallons; two days later 115 gallons; three days later 85 gallons, and at

Completed Metalium Joint before the Gate has been Broken Off



Metalium Furnace

Lead Furnace Converted into Metalium Furnace by Reducing Grate Area to an 8-inch Circle

Melting Metalium Over an Open Fire on a Small Job

a subsequent reading of the meter, the line was practically tight. In this connection it should be remembered that authorities are not wanting that decree a lead jointed pipe line tight when the leakage does not exceed 300 gallons upon the same basis of measurement. A mile of 24-inch pipe, which showed a considerable initial leakage when first put into service, was subsequently tested and found to be practically bottle tight.

Again, the accounting department of the Metropolitan Water District affords monthly statements of water passing through all consumers' meters, and these statements show that more than 83 per cent of the water supplied to the city of Omaha (Venturi meter measurement) is accounted for through such consumers' meters, and this notwithstanding the fact that there are still about 500 flat-rate services in use and some 600 sewer flush tanks unmetered. The estimated water used by these unmetered services, together with that used in building, for street flushing and sprinkling, the flushing of sewers and water pipe trenches, and the water required for fire service, is estimated at 5 per cent, thus making the total water accounted for 88 per cent of that supplied to the District. When it is remembered that some water systems cannot account for more than 60 per cent of the water supplied, it suggests that the mains of the Metropolitan Water District are reasonably tight.

Metalium is of a dark greyish luster, and is supplied commercially in globular form, put up in bags of 100 pounds each. In use, it is melted and poured just as in the case of lead. However, while the temperature of molten lead when poured is immaterial, in the case of metalium the temperature is important; it must not be too hot. It is not difficult to tell when metalium is ready to pour, as it is then a thin, nearly black, oily appearing liquid. If too hot, molten metalium is inclined to thicken and does not pour readily. The difficulty of firing the ordinary lead furnace so as to limit the temperature renders it unsuitable for metalium. However, if the grate area of such a furnace is choked down with fire brick and clay so as to leave the open surface but 8 inches in diameter, such a furnace can be utilized. But the best plan is to secure the specially designed metalium furnace, as it is light, cheap, and admirably arranged for temperature control. It is surprising the small amount of fuel required—either coal or wood. In the Water District work old discarded lumber is chopped up for this purpose.

Furnaces using oil or gasoline are also satisfactory but are difficult to keep going in a high wind. It is very important that the bell

and spigot of the joint to be run should be thoroughly clean and free from oil or grease. For this reason unoiled jute yarn, only, should be used for packing. Tarred yarn or yarn that is not free from oil or grease must be avoided. As a matter of fact, practically all initial joint leakage can be obviated if particular care is exercised in cleaning and keeping clean, each bell and spigot, using a putty knife to remove all lumps and blisters in the pipe coating. One of the Water District's most successful foremen does this, and after the joint is yarned, he inserts a loose strand of yarn so as to keep the joint free from dirt until poured, a practice that will be found highly profitable in connection with lead joints.

Any form of joint runner can be utilized, smearing it with wet clay before placing it around the pipe. The gate must be made larger than for lead and should be at least 6 to 8 inches high above the spigot. In the Metropolitan Water District work, clay is the material used for making gates in jointing pipe. In this connection, a round wooden gate peg is very useful. This peg is conical in form, 10 inches long, 2 inches in diameter at the bottom, and 3 inches at the top. The bottom of the peg is inserted between the ends of the joint runner where they come together to form the gate, then clay is built up about this peg, which is then turned around once or twice and withdrawn leaving a well formed gate of the right height.

The metalium gate buttons can be remelted, but it is important that they should be thoroughly cleansed and broken up before being put back in the melting pot.

From the foregoing, it is evident that the technique of this jointing material is simple, and it can be easily mastered by the ordinary workman; moreover, when faithfully carried out, it will afford highly satisfactory results. However, it should be remembered by those contemplating the use of metalium, that they will arouse the resentment of calkers, for the very good reason that the adoption of this material means their practical elimination. This was the experience in Omaha. Every calker at once insisted that metalium was a failure, and tried to make it a failure, even going so far as to throw dirt surreptitiously into the joints ready to pour. Failing in this, they sent their friends to the Water Board with warnings as to the dangerous innovation that was being attempted. All this, now, of course, is past and gone, so far as the Metropolitan Water District work is concerned, but others attempting to use this material will probably meet with the same experience, as human nature is the same the world over.

NEW DESIGN OF SCREEN CHAMBER[1]

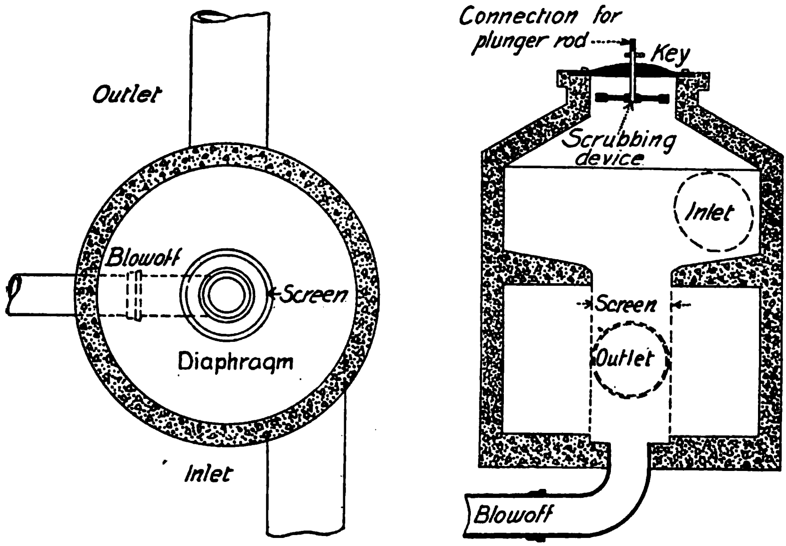
By John H. Lance

In the use of water for supply purposes, its freedom from foreign bodies is of prime importance. While ordinarily the water of driven or dug wells or infiltration galleries is free from detritus, all stream, reservoir and lake supplies require careful screening before the water is admitted to the distribution system. Among the bodies to be removed from the water are grass, leaves, sticks, bits of bark, and fish; and by far the most troublesome of these are leaves in all stream and small reservoir supplies. Masses of water grass only occasionally move to the point of intake; sticks usually only by reason of a high stage of water in the source of supply. Unlike these substances, which do not often of themselves form, by lodging against the screen, a tight barrier to the passage of water, leaves may practically seal the screen and effectually shut off the supply. This result may be caused also, but rarely, by small fish, of such a size as to be unable to resist being carried by the current at the intake. When they have been held against a screen for twenty-four hours, these fish make a tight seal and a very difficult coating to remove; one that is not readily released when the pressure is removed, as are leaves. Only the rarity of conditions favoring such occurrences spares the water-works operatives a vast amount of trouble. On the other hand, the leaf nuisance, especially in supplies from small reservoirs and streams, makes constant demands upon the attention of the operatives for a considerable part of the year.

The customary method of removing these substances is to install at the intake of the supply main, a screen affixed to the pipe, or two sets of screens in series, which may be drawn up out of the water for cleaning and replaced again for service. The former arrangement which is applicable only to very small depths of water on the screen, is economical in first cost, but its use has not always proved so economical; for owing to any one of many causes the screen might not receive the necessary attention at the very time when it was most needed. The latter arrangement necessitates a consider-

[1] Read before the Richmond Convention, May 9, 1917.

able structure to hold the screens in place and house them while being cleaned. If the reservoir is of great depth the process of cleaning is tedious and expensive, involving, as it does, the hauling up of all the screens in one set and their replacement, for each cleaning. During the time of cleaning the upstream set, the downstream set is receiving leaves and trash. While the cleaning of this set takes place, much of the débris lying against the screen, and any fish between the two sets, go down into the supply main to appear at the various fixtures of consumers or block the operation of meters.



A NEW TYPE OF SCREEN CHAMBER

To obviate these difficulties the pressure screen-chamber here described was designed. It consists essentially, of a vertical cylinder divided by a horizontal diaphragm into two compartments. The upper or inlet compartment communicates with the lower or outlet through a circular opening in the diaphragm and thence through the meshes of an open-ended cylindrical screen resting in the lower compartment, of a diameter nearly that of the opening. The lower end of the screen is concentric with the end of a blow-off pipe with a gate valve on it, normally closed. The inlet pipe enters the inlet compartment tangentially, while the outlet may leave in any direction relative to that of the inlet, preferably in a radial position. Any

flow from the inlet pipe sets up a whirling motion in the water in the upper compartment. In passing through the screen cylinder, it has a circumferential as well as a downward motion, which, owing to the passage of water through the meshes of the screen, diminishes as the bottom of the screen is approached. The result of this is to confine, largely, the foreign matter carried by the water to a central cone the base and height of which are approximately those of the screen. The upturned end of the blow-off pipe being made of nearly as great a diameter as the screen, this results in an accumulation of débris directly in the pipe. When blocking of the screen has progressed to a point at which there is a noticeable loss of head at the screen, as measured preferably by a mercury U-tube or a differential gage, the blow-off gate is opened. The head in the blow-off pipe is then reducted to zero, or nearly so, the hydraulic gradient from the reservoir to the screen chamber is increased, and the high velocity established is transmitted directly to the water passing diagonally downward over the face of the screen and out the blow-off pipe. Ordinarily, the cleaning of the screen is accomplished in about the time that it takes to open and close the blow-off gate. If it is desired to maintain a considerable continuous flow through the outlet pipe, the blow-off gate need not be opened wide, in which case the operation will require a longer time. Under no conditions is an appreciable amount of water wasted.

Also incorporated in the design is a hollow segmental brush, for use in cases when the screen does not have attention for such long periods that a deposit of small fish is not readily removed by the flowing water.

For the intake pipes of pumping stations the devices are best set in batteries of two, so arranged that one can be put in service while the other is being cleaned. In this case the cleaning is preferably done by jets of high-pressure water directed downward from the edge of the diaphragm across the screen. Where electric power is available, the use of proper contact devices at the point of measurement of the loss of head at the screen will make the entire screening operation automatic, both for gravity and pumping supplies.

For use with a gravity water supply, the devices have been found to operate most successfully between the heads of 40 and 60 feet, though there is no valid objection to their use at other heads, under certain conditions. They are made entirely of reinforced concrete with the exception of the manhole cover, which is of cast iron.

The principle of pressure screening, from which the design was developed, was first suggested by O. M. Lance, General Manager of the Spring Brook Water Supply Company. The operation of the screen chambers has been found to be so economical and efficient that they have been adopted as a standard by the above named company. As convenient, all its supply lines, 20 in all, will be equipped with the new device, and the old sliding screens removed, only bar screens being left in place. The new screen chambers have been patented.

REMOVAL OF IRON, MANGANESE AND CARBON DIOXIDE FROM WATER[1]

Robert Spurr Weston: There was a very interesting case of decarbonation at a plant which the speaker cannot refer to by name. The works were originally supplied from ground-water sources. Lead poisoning developed to an alarming degree, and as a result the ground-water supply was abandoned in great part and slow sand filters installed, taking a very highly colored ground water, purifying it to a very good degree and supplying it to the city. The ground water in the beginning contained 55 parts per million of carbonic acid. When the slow sand filters were started, of course the carbonic acid content of the water furnished to consumers was reduced to practically that of the surface water, less than 10 parts per million, and the corrosion of the lead pipe services stopped immediately. After a period of about fifteen years of operation of the sand filters much coagulated brown vegetable matter accumulated in the sand, and the filters were so efficient that they converted this brown vegetable matter into carbonic acid, so that three years ago the amount of carbonic acid in the sand filter effluent was nearly what it was in the well water some years before and, strange to say, the wife of the attorney of the water company developed a very severe case of lead poisoning, and the matter had to be attended to.

Experiments were made similar to those made by the author and the conclusion was reached that aeration alone increased the corrosive action of the water on the lead surfaces to a great degree, and that the carbonic acid which was left in the water after aeration was more corrosive than the original amount without the oxygen. It was found, however, that the addition of very small amounts of either lime or magnesium oxide, the latter particularly, would practically prevent the corrosive action on the lead. The amount added was about 8 parts per million of quicklime or 6 parts per million of magnesium oxide, equivalent to about one-half grain to the gallon.

[1] Discussion of a paper by Frank A. Barbour on "Decarbonation and Removal of Iron and Manganese from Ground waters at Lowell, Mass.," in the Journal for June, 1917

This slight addition increased the hardness somewhat, but it was decided to apply the method. The addition of lime with aeration did not produce the best results. The water at that time contained over 1 part per million of lead and was treated with about 10 parts per million of lime.

This application was immediately followed by a reduction in the amount of lead and now, nearly at the end of the third year of operation, the lead in the water in ordinary use has been reduced to about 0.08 part per million; and in conditions where the water stands in services over night, to about 0.26 part per million; in both cases considerably less than the permissible amount. As to "permissible amount," the speaker believes that any lead at all in water is injurious, because the result is cumulative. The people noticed a slight increase in hardness after treatment, less than 35 parts per million but they have made no complaint. All danger of lead poisoning seems to have been averted forever. This method is used in England in treating certain waters that are acid, and the treatment with lime simply cures the acidity of the water due to carbonic acid or organic acid.

The method of removal of iron and manganese from water must be predicated upon the character of the water. Iron and manganese dissolved in water will nearly always precipitate out as iron or manganese rust. Practically all that we can do is to hurry the operation. Where the water is hard, as it is in some of the western states and in Germany, simple aeration and filtration is all that is required; in these cases it does not seem to make much difference whether you use slow filters or rapid or whether you use tricklers or not; but the removal of small amounts of iron from soft water is more difficult. Small amounts of iron in conjuction with manganese, or in conjunction with coloring matter, require more time than where the amounts of iron and manganese are large.

The most difficult water that the speaker has had to treat has been in his own house; the water has only 0.5 part per million of iron and considerable manganese, but a great deal of coloring matter. Another difficult case was the water supply at Cohasset, Mass., where a mechanical filter was first installed, which removed the iron perfectly and also the manganese without the use of coagulants. Within the last three or four months the color of the raw water, due to a near-lying peat bog, has increased so greatly that it has been necessary to add sulphate of aluminum to the water before passing it to the filter.

As to the choice of filters, the speaker believes that when a sand filter operating at a rate of 10,000,000 gallons per acre daily will do the work it will prove cheaper in practice, as a rule, than a mechanical filter at a rate of 125,000,000 gallons. Where the mechanical filter rate can be increased, where the head conditions are favorable, it may prove cheaper, and where the iron or manganese respond readily to treatment there is no reason why a mechanical filter should not be used where economic conditions favor it.

Recently, Dr. Corson prepared a paper in which he ascribes a great deal of the removal of manganese to the presence of a catalytic agent, that is, an agent which carries oxygen or effects the removal of the iron by catalysis. In Germany they have made similar experiments; they have, for instance, used shavings impregnated with tin oxide and various compounds supposed to be oxygen carriers, and passed these iron waters over them, with good results. However, it appears that other German investigators have shown that the same results can be obtained with sand filled filters. It has been shown that the film of iron or manganese hydrate on the surface of the sand will absorb oxygen, store it, and give it off. So the speaker is not yet in a position to accept the theory of catalysis, that it is the carrying of the oxygen by the oxide or the hydrated oxygen precipitated on the filter material which does the work; but rather that the iron and manganese which are readily oxidized are held in a fine collodial suspended condition and are absorbed by the film on the sand and held there until coagulation can take place, after which the film gradually increases in bulk until it sloughs off the trickler and is precipitated in the subsiding basin, or is removed from the surface of the sand filter.

At Middlesboro, in a plant somewhat similar in design to the author's but very much smaller, it was found that during the first year the manganese was reduced from about 0.56 to 0.15 part per million, but during the second year it was completely removed. The iron at Middlesboro has been reduced to an average of about 0.25 part per million.

During experiments at Brookline, contrary to the Lowell experience, it was found that the more contact of the water with air the better were the results that could be obtained. Again the speaker would say that what will work with one water will not work with another.

At Stargard, in Germany, where the iron and manganese are removed quite readily, the red discoloration or precipitation of iron

is observed in the upper few inches of the gravel filter. Below that there are about 6 inches of clean gravel where neither iron nor manganese is being removed. Below the clean layer is a black layer where the manganese has accumulated, and below that clean gravel again, showing that the manganese oxidizes much more slowly than iron and requires more time, more contact, more help. It is for this purpose that subsiding basins, coagulants, coke tricklers, etc., are used to treat soft colored manganiferous waters before filtration.

JOSEPH RACE: The speaker could corroborate the statements just made regarding the plumbo-solvency of the waters in the north of England. Almost all water derived from the uplands situated near the Pennine range was in this category and required treatment of some kind to rectify this condition. The generally accepted hypothesis in England was that the action on lead was due to the presence of humic and other organic acids and it had been found that the plumbo-solvency could be rectified by the addition of caustic lime or soda or carbonates of lime or soda. The experiments made by Heap at the Manchester University appeared to indicate that oxygen and not carbonic acid was the most potent factor in the solution of lead, but as these results were obtained with waters that are very different from that treated by the author the problems are not analogous.

EDWARD BARTOW: With respect to iron removal in Illinois, two methods are employed. One is used at Freeport, where lime is used to remove the iron, the other at Champaign, where aeration and filtration with mechanical filtration removed about 2 parts per million, giving very satisfactory results.

Recently the Illinois Water Survey was asked for advice concerning a proposed water supply for Johnson City in the coal mining district. The problem was to remove 95 parts per million of iron from water having 4200 parts residue. Compare that with the 2 parts per million of iron which it is necessary to remove at Lowell from a water having a residue of about 34 parts per million, less than 0.01 per cent of the amount in the Johnson City water supply. It was proposed to remove the iron by aeration and mechanical filtration. The resultant water could not be very satisfactory because the treated water would contain about 3000 parts per million of sodium sulphate, which would surely have a bad effect on those not accustomed to its use.

For manganese removal, the speaker has tried experimentally the zeolites and also aeration and filtration. The zeolites as used in Europe will remove manganese; but manganese dioxide itself, or manganese dioxide developed on the sand grains, was efficient. The manganese dioxide was developed on the sand either artificially by means of alkali and a manganese salt or by very slow accretion after the filter was put in operation. There are two plants in the state which are removing manganese by means of mechanical filters where the sand grains have been coated with the manganese dioxide.

It is interesting to note the change in operating at a plant near Berlin, Germany; formerly aeration over baffles followed by slow sand filtration was used, but in a new plant opened in 1914 aeration by spraying, followed by a mechanical filtration, is used.

Samuel B. Applebaum: There are two questions the speaker desires to ask the author: First, in regard to the effect of increasing the amount of dissolved oxygen in the water upon aeration; has the author made any experiments as to the effect of aerated water on iron pipes in addition to his experiments on lead pipes, in order to ascertain the relative corrosiveness? He observed the interesting fact that the use of aeration was preferable to the use of an alkali to eliminate the corrosive effect of the water on lead. It would have been interesting if he had also tried experiments to ascertain whether the same effect, or the contrary, was true regarding the corrosiveness of the aerated water as compared with lime-treated water upon iron piping.

The second question is whether the author has made any experiments with the use of zeolites coated with higher oxides of manganese for the removal of iron and manganese in the Lowell supply? Abroad there are many municipal plants making use of these contact zeolites for the removal of iron and manganese from water. There are six or seven plants in operation today in Germany, notably those at Dresden, Glogau, and Wilhelmsburg, which are removing iron and manganese by this method. There is also one plant in England near Liverpool that is using these contact zeolites for the removal of iron and manganese followed by a sodium-zeolite plant for the removal of hardness. In this country there are two small municipal installations using this method, one at Helmetta, N. J., and the other at Weyanoke, Va., where the treated waters are free from iron and manganese, and are used for domestic purposes.

SOCIETY AFFAIRS

ILLINOIS SECTION

The Illinois Section held a meeting at Peoria on November 15, 1917, 47 members and guests being present. Visits were made to wells 7 and 8 and to the main pumping station of the Peoria water works where luncheon was served, and to the plants of the Avery Manufacturing Company, the Holt Manufacturing Company and the Keystone Steel & Wire Company. Dinner was served at the Creve Coeur Club, and at the meeting afterward H. B. Morgan described the Peoria water-works and read a paper on "The Deep Water Way," and C. B. Burdick read a paper on the "Water Works of Camp Grant."

NEW MEMBERS

Active

Jesse H. Wilson, City Engineer, Idaho Falls, Idaho.

Marion A. Jensen, Chief Engineer and Superintendent of Water Works, Nebraska City, Nebraska.

Federico Klein, Electrical Engineer, San Salvador.

Abel Wolman, Sanitary Engineer, Baltimore, Maryland.

Wm. J. Leach, Superintendent and Chief Engineer, Fergus Falls, Minnesota.

J. Mitchell Heffelfinger, Engineer, Illinois State Water Survey, Urbana, Illinois.

Frank E. Howard, President Water Board, Hartford, Connecticut.

Fred. D. Berry, Secretary, Water Board, Hartford, Connecticut.

C. M. Saville, Manager and Chief Engineer Water Board, Hartford, Connecticut.

Clarence F. Ames, Superintendent Water Works, Norwich, New York.

Charles Rapelge Wyckoff, 150 Nassau Street, New York, New York.

Richard W. Sherman, 104 South Lake Avenue, Albany, New York.

James A. Shepard, Bisbee-Naco Water Company, Bisbee, Arizona.

A. D. Leerskov, Superintendent Water Works, Brush, Colorado.

Vratislav Adolph Zehr, Mechanical Engineer, Quincy, Illinois.

Warren G. West, Superintendent and Secretary, Water Company, Leadville, Colorado.

Cornelius M. Daily, Engineer in Charge Supply and Purification Department, St. Louis.

Dale L. Maffitt, Chemist and Bacteriologist, Des Moines Water Company, Des Moines, Iowa.

Corporate

Manhasset-Lakewood Water District, Manhasset, New York.

Citizens Light, Heat and Power Company, Tracy, Minnesota.

OBITUARY

D. C. Crandall, Tupper Lake, New York, December 19, 1917.

Albert Blauvelt, Chicago, Illinois, January, 1918.

Howard E. Ahrens, Reading, Pennsylvania, February 26, 1918.

Harry A. Lord, Ogdensburg, New York, March 11, 1918.

ROLL OF HONOR

Following are additional names to the Roll of Honor printed in the March JOURNAL:

ATKINSON, MYRON H. (son T. R. Atkinson), O.T.C., Camp Devens, Massachusetts.

BAKER, FREDERICK W. (son M. N. Baker), O.T.C., Camp Upton, New York.

CLAIBORNE, HERBERT A., Lieutenant Signal Reserve Corps, Aviation Concentration Camp, Morrison, Virginia.

FALLER, C. P. (son C. Faller), Lieutenant 11th Infantry, Camp Forrest, Georgia.

HYMMAN, GORDON (son H. Hymman), Sergeant Co. A, Royal Canadian Infantry, Military Convalescent Home, Guelph, Ontario.

KILPATRICK, JOHN DOUGLAS, Lieutenant Colonel Quartermaster Corps, Constructing Quartermaster, Camp Wadsworth, Spartanburg, South Carolina.

LONGLEY, FREDERICK J., Lieutenant Aviation Section, Signal Corps, 271st Aero Squad, Ellington Field, Houston, Texas.

MALLALIEU, WILLARD C., Sanitary Corps, N.A., Camp Greenleaf, Georgia.

LETTON, H. P., Captain Engineers, N.S.R.

MOHLER, BRUCE M., 1st Lieutenant Sanitary Corps, N.A., Army Medical School, Washington, D. C.

RANDALL, W. T. (son W. H. Randall), Signaller 108th Battalion (Canada), B.E.F., France.

WILCOX, WILLIAM F., JR. (son W. F. Wilcox), Sergeant 106th Supply Train, 31st Division.

WOOD, EDWARD R., JR., Captain 18th Field Artillery N.A.

WITH SUPPLEMENT

VOL. 5 NO. 3 SEPTEMBER, 1918

PROCEEDINGS 38TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED IN MARCH, JUNE, SEPTEMBER AND DECEMBER BY THE

AMERICAN WATER WORKS ASSOCIATION

At 2419–21 Greenmount Ave., Baltimore, Md.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Subscription price, $5.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917,
authorized August 6, 1918

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 5 SEPTEMBER, 1918 No. 3

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Charles R. Henderson, President, 1918-1919

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

VOL. 5 SEPTEMBER, 1918 No. 3

COMMENTS

DISCUSSIONS

When the Association adopted the report of the last Publication Committee it thereby approved the recommendation in that report concerning methods of making the JOURNAL more helpful and interesting to the members. One of these methods is to have the JOURNAL record the progress of important work. It is while work is in progress that it is alive; when it is finished it may be interesting and useful, but it is not interesting in the way that a job in hand appeals to us. Take the report of the Committee on the Mechanical Analysis of Sand in this number, for instance; it is a progress report, intended solely for the information of the members concerning the work of this committee and not approved in all respects by the members of the committee. But it gives an idea of one feature of the work the committee has been doing, and in this way keeps our members posted regarding a topic that was the subject of animated discussion at the Cincinnati convention.

When a piece of work has advanced beyond the stage when discussion is useful it is so far along toward completion that a good many of us will not take the time to read about it. But if we know that those investigating a subject are still discussing it critically our ever-persistent curiosity leads us to follow the discussion, if we are fortunate enough to be able to do so. The things that are discussed are the live things. The place where they should be publicly discussed is in our JOURNAL. This thought was the basis of the recommendation made by the last Publication Committee. So far as the

present Publication Committee is able to carry out the recommendation it will do so, but the members of the Association should keep in mind that these "Comments" will only be of the greatest value when they all contribute to them, or send suggestions which the Publication Committee can utilize in obtaining information of immediate value to the fraternity.

CARLETON E. DAVIS.

SHIP YARD SANITATION

So much has been said about the sanitary work done by the government at the camps and cantonments that what Mr. Greeley says in this number about sanitation at the shipyards is a timely tribute to a group of men which has been doing a fine piece of work without receiving any recognition for it. The enormous shipbuilding program of the Emergency Fleet Corporation called for the construction of new villages and new transportation facilities almost overnight. The need for ships has been most pressing. The managers of these yards thought of ship ways and shops and tracks and storage; they had no time to think of sanitation, except casually. It was to help them keep their mushroom enterprises safe in a sanitary sense, that Colonel Doane was engaged. He and his men have been out on the job most of the time. During the five months I was employment manager of the Emergency Fleet Corporation I saw him only once, at a staff dinner. He was too busy to waste any time in an office chair. But he has kept the ship yards in good sanitary condition in spite of serious difficulties, and he has done such a satisfactory piece of work that nobody was surprised when the War Department told him recently to get ready to return to the army.

J. M. GOODELL.

HOW TO OBTAIN A PRIORITY ORDER AT WASHINGTON

Municipalities and public utility companies all over the country are experiencing such difficulty in obtaining materials for operation, maintenance and new construction, that a brief statement of their obligations to the nation, as viewed by the administration at Washington, is desirable at the present time. Cities and utility companies must remember that when President Wilson told us to "give until it hurt" in order to bring the war to the earliest possible com-

pletion, his appeal was to communities and corporations as well as to individuals. The general policies which are rapidly going into effect in Washington are based on this thought, that communities must give their aid by deferring to a later day all unessential work. The difficulty is to determine what is essential and what unessential, but the War Industries Board has made enough rulings to throw light on its position in regard to the prosecution of various classes of work.

In maintenance and repair work, necessary for the upkeep of plants furnishing essential service to communities, the War Industries Board grants every assistance in its power. It cannot accomplish an impossible task, however. There are some sections of the country where important war time orders call for every barrel of cement that can be furnished by mills normally supplying that district, and the United States Railroad Administration does not favor shipments from abnormal sources of supply for a district. Every pound of steel that can be turned out of our furnaces is needed for war-time purposes, just now. Not long ago a branch of the War Department was so hampered by lack of steel that it sent out representatives to comb the jobbers' stocks and blacksmith supply houses in a large section. Pig iron is needed for many war purposes the civilian knows nothing about. In some sections north of the Potomac and Ohio and east of Indiana, the railroad congestion is so severe that important branches of the government are placing no orders there for the present. In short the government is experiencing great difficulty in securing materials to win the war, and consequently the managers of water works must not expect anything else.

While there is a general agreement that existing public utilities should be maintained in an efficient condition, there is very little probability that new construction will be possible. A suburb which has gone without water mains or sewers until now can probably go without them a year or so longer. A water plant which has been furnishing unfiltered water for some years probably cannot make an effective plea before the Washington authorities that an unsanitary condition exists which demands immediate relief. A water department in a city where the growth has been only normal will probably experience much difficulty in securing materials for new dams or pumping stations, for the federal administration is not hesitating to put the country on short rations even of essentials in

order to back most effectively our lads on the battle grounds and high seas. Everybody agrees that water of unquestionable purity and ample quantity is most desirable, but our soldiers and sailors are sometimes going without it and we can learn, as they do, to be careful of what we have.

In short, then, no water works manager should attempt to obtain materials which are not absolutely necessary to maintain his plant in its present condition, unless the new extensions are absolutely necessary for war-time industries. Every day thousands of letters praying for relief of one kind or another reach Washington, and the claim made for the relief is that the community or the district is engaged in war work very largely. Such petitions are never granted, for generalities are not accepted as evidence in Washington. Every application for relief must be accompanied by positive proof that if the application is not granted the active prosecution of the war will be checked, a heavy previous investment will be seriously impaired, the health of a large number of people who cannot be moved elsewhere will undoubtedly be placed in grave danger, or a large financial loss and great inconvenience to many persons will arise from stopping construction undertaken before the beginning of the current year.

In each case it is absolutely necessary to explain what alternative remedies have been considered and why they have been deemed inferior to that requested. The statement that larger mains must be laid to meet the needs of a growing population in any section of a city is worthless as an argument at Washington. There should be a map of the section of the city, showing the location and size of the mains serving it, records of the water pressure at different points if this is important, a statement of the number of consumers, and an explanation of what the water department is doing to prevent water waste. In short there must be just as complete a technical and administrative demonstration of the soundness of the appeal as a bank demands when it receives an application for a loan. This application should be sent to the Priorities Division, War Industries Board, Washington. Do not send a delegation or even a single representative and above all do not ask a member of Congress to help, for he cannot do anything that a proper application by mail will not accomplish better and more quickly. Applications for relief should be made out on forms which can be obtained from the Priorities Division, with instructions regarding their use.

What has been said above is merely a restatement of the resolutions passed by the War Industries Board on March 21, 1918, and published in all the leading newspapers and trade journals of the country. In order to make this important matter perfectly clear to the members, the resolutions are printed here.

WHEREAS, it has come to the notice of this Board that new industrial corporations are being organized in different sections of the United States, for the erection of industrial plants which cannot be utilized in the prosecution of the war, and

WHEREAS plans are being considered by certain states, counties, cities and towns for the construction of public buildings and other improvements which will not contribute toward winning the war, and

WHEREAS the carrying forward of these activities will involve the utilization of labor, materials and capital urgently required for war purposes; now, therefore, be it

Resolved, by the War Industries Board, That in the public interest, all new undertakings not essential to and not contributing either directly or indirectly toward winning the war, which involve the utilization of labor, material and capital required in the production, supply or distribution of direct or indirect war needs, will be discouraged notwithstanding they may be of local importance and of a character which should in normal times meet with every encouragement; and be it further

Resolved, That in fairness to those interested therein notice is hereby given that this Board will withhold from such projects priority assistance, without which new construction of the character mentioned will frequently be found impracticable, and that this notice shall be given wide publicity, that all parties interested in such undertakings may be fully apprised of the difficulties and delays to which they will be subjected and embark upon them at their peril.

The Priority Committee, and particularly its Chairman, is indebted to the editor of the JOURNAL for securing an interview with officials of the War Industries Board and preparing the above statement outlining the situation concerning priorities. The Committee endorses this statement and desires to make it its own, except in so far as the labor in obtaining it is concerned.

PRIORITY COMMITTEE,
By C. E. Davis,
Chairman.

THE PRACTICABILITY OF ADOPTING STANDARDS OF QUALITY FOR WATER SUPPLIES*

By Robert B. Morse and Abel Wolman

In spite of the fact that the attempt to establish a so-called standard to serve as a basis for interpreting or classifying the quality of potable waters has met with but little success in the past, endeavors are still being made to standardize the consideration of analytical results so as to eliminate personal judgment as a feature of interpretation. The difficulties besetting these efforts, such as the undetermined significance of the bacterial test made by various methods, the importance of varying chemical content and the evidence of sanitary surroundings, are still present in probably a greater degree than in the past, on account of the development of the science of water bio-chemistry and the added confusion created by the ever changing methods, media, temperatures, and differentiations.

Before establishing a measure of the quality of a potable water, it is necessary to determine by what units such measurements are to be evaluated. In the case of water supplies, the choice of appropriate units becomes difficult, since the question immediately arises as to whether the bacterial count, the B. coli test, the chemical determinations, or the sanitary inspection, should be the sole criterion; or if a combination of these factors, as to what their relative importance should be in any proposed unit of measure. Manifestly a standard in its simplest terms could be predicated upon any single one of the above-mentioned units, if we assume that such a standard would fulfill the requirements of a universal measure of quality. Even then the problem still remains of deciding what unit of bacterial content, for instance, shall be chosen as the basis for comparison.

* Read at the St. Louis Convention, May 15, 1918. Discussions of this paper for publication in a later number of the Journal may be sent to John M. Goodell, Cosmos Club, Washington.

A unit of measure must be founded upon the existence of an absolute uniformity of condition and of material which can be made to serve as the immutable basis for future comparative readings. The unit of length, for example, is that distance between the ends of a bar of definite material, in a definite place, measured and corrected for predetermined conditions of atmospheric pressure and temperature. Such a unit immediately establishes a precise standard by means of which further measurements of length under all conditions may be carried out. The search for a "quality standard" for water should be first directed, therefore, towards determining whether there are available any definite units in sanitary science which can serve as the basis for a standard.

If the water analysts have agreed upon well-defined methods of water analysis, then the evaluation of a standard would be at least possible, if not valuable, for interpretation. In order to learn whether any degree of uniformity existed in the laboratory examination of water supplies, a questionnaire was submitted to 33 state department of health laboratories in the United States. Thirty-two answers were received and sufficiently detailed information was obtained to warrant the conclusions later to be discussed. With these data at hand, the practicability, at the present time, of formulating a standard of quality for water, in the light of present day analytical practice, may be discussed with more precision.

Total bacterial count. The total number of bacteria in a stated quantity of water has been used frequently in establishing a maximum allowable pollution in potable waters. One of the more recent of these is the requirement of the United States Treasury Department that water supplied to common carriers should contain no more than 100 bacteria per cubic centimeter (37°—24 hours—agar). The creation of such standards presupposes a unanimity of opinion as to the significance and importance of particular bacterial counts obtained by definite procedures, over others found by any other methods. Such an agreement would be reflected, of course, in the routine procedures of laboratories. The data in table 1 disclose, however, a disconcertingly wide difference, rather than agreement, of attitude toward the various methods. If official water analysts differ in their choice of the method of making total counts, it is reasonable to conclude that their disagreement would be even greater in a choice of a "standard" total count. Since the relative significance, for instance, of the total number of bacteria on a plain

TABLE 1

Method of obtaining total bacterial count in laboratories of various state departments of health

NAME OF STATE	20°C.				37°C.				
	Gelatine		Agar		Gelatine	Agar		Lit. Lact. Agar	
	48 hrs.	96 hrs.	48 hrs.	96 hr.	48 hrs.	24 hrs.	48 hrs.	24 hrs.	48 hrs.
California						+			
Connecticut	+					+			
District of Columbia			+ (a)						
Florida							+		
Georgia						+			
Illinois	+					+			
Indiana						+			
Iowa			+					+	
Kansas	+					+			
Kentucky						+			
Maine	+					+			
Maryland			+			+			
Massachusetts				+				+	
Michigan						+			
Minnesota				+					
Missouri						+	+		
Montana						+			
New Jersey			+			+		+	
New York					+	+ (b)			
North Carolina	+							+	
Ohio			+			+			
Oklahoma						+			
Pennsylvania							+		
Rhode Island			+					+	
South Carolina						+	+		
South Dakota							+		
Vermont						+			
Virginia						+			
West Virginia							+		
Wisconsin		+ (c)							+
Wyoming	+						+		

NOTE: Data in above table obtained by letter in 1917 from officials of various state departments of health.

(a)—25°C.

(b)—Infrequent.

(c)—15° to 20°C.

agar plate at 37°C., as compared with the count on a gelatine plate at 20°C., is still a moot question, it is clear that more confusion in interpretation will result when several additional different combinations of media, temperatures, and periods of incubation are to be considered.

It is also of striking interest to note that, in spite of the fact that the 37°C. agar count at twenty-four hours incubation has been for several years an official standard procedure of at least two organizations (American Public Health Association and United States Treasury Department), only 19, or approximately 60 per cent, of the laboratories in question have seen fit to use this exact procedure as a routine measure. The percentage is undoubtedly higher than that which would represent the individual opinions of the analysts in these laboratories, in view of the fact that some of them have adopted the aforementioned methods on account of their official stamp rather than as a result of the conviction that they are superior to others. This conclusion is borne out by the fact that it has been by no means firmly established that the bacterial count, obtained as outlined by the Federal requirements, serves as the best index to the quality of a drinking water. In the light of the data illustrating the wide discrepancy in the method of obtaining the bacterial count, it would appear that effort should be directed towards further study of individual types of bacteria and their relative significance rather than towards an attempt to predicate a standard upon such an elusive and variable factor as the general bacterial count.

B. coli. An index to sewage pollution in potable waters is an excellent asset in determining the safety of a supply if it "indicates." Some years ago, perhaps, the presence of B. coli in small quantities of water was considered sufficient evidence upon which to condemn the supply. He certainly would be venturesome who would issue a manifesto today as to the allowable frequency of B. coli in a safe water. He would indeed be skillful who can gather sufficiently consistent data out of the present chaotic conception of the significance of B. coli, and of how to obtain it, to be able to establish even a fairly elastic measure of quality.

Table 2 illustrates, for instance, that the use of a medium for testing even the elementary phenomenon of gas formation is still open to question, while the significance of gas formation itself is disputed by authorities. Considerable evidence has supported previously the use of lactose bile, but the wind has apparently shifted in recent

TABLE 2

Method of making presumptive tests for B. coli in laboratories of various state departments of health

NAME OF STATE	MEDIUM USED		PERIOD OF INCUBATION	
	Lactose broth	Lactose bile	48 hours	72 hours
California	+		+	
Connecticut	+		+	
District of Columbia		+	+	
Florida	+		+	
Georgia	+		+	
Illinois	+		+	
Indiana	+		+	
Iowa	+		+	
Kansas	+	+	+	
Kentucky	+		+	
Maine		+	+	
Maryland	+		+	
Massachusetts	+		+	
Michigan	+		+	
Minnesota	+		+	
Missouri	+		+	
Montana	+		+	
New Hampshire		+	+ (c)	
New Jersey	+	+ (a)	+	
North Carolina		+	+	
North Dakota				
Ohio	+		+	
Oklahoma	+		+	
Rhode Island	+		+	
South Carolina		+		+
South Dakota	+		+	
Tennessee				
Vermont	(b)		+	
Virginia		+	+	
W. Virginia	+		+	

NOTE: See note in table 1.
(a) Infrequent.
(b) Lactose neutral red.
(c) Thirty-six hours.

years and the balance now rests upon the importance of lactose broth as a better medium for an initial B. coli test. Each day brings forth another experimental factor to make the confusion greater as to the significance of lactose fracture.

The data given in table 2 show a close agreement in the laboratories as to the necessary period of incubation in the B. coli presumptive test. In the face of the almost universal choice of a forty-eight hour period, it is found in the Maryland State Department of Health laboratory that about 25 per cent of all typical B. coli isolations are obtained from those tubes which show gas only after seventy-two hours incubation. It is somewhat doubtful, with the evidence shown in table 3, whether even the apparently settled question of period of incubation is not still debatable.

TABLE 3

The effect of an increased period of incubation in the presumptive test upon the possible number of confirmatory tests

Total number of tubes incubated and giving gas = 495

GAS FORMATION AT END OF	NUMBER TUBES SHOWING GAS		PER CENT TUBES SHOWING GAS		NUMBER CONFIRMED		PER CENT OF TOTAL TUBES CONFIRMED	PER CENT OF TOTAL SAMPLES CONFIRMED
	Total	Additional	Total	Additional	Total	Additional		
hours								
24	18	18	3.6	3.6	17	17	6.2	3.4
48	263	245	53.1	49.5	197	180	66.0	36.0
72	448	185	90.5	37.4	264	67	24.6	13.4
96	495	47	100.0	9.5	273	9	3.3	1.8

NOTE: Data obtained from routine analytical determinations in laboratory of Maryland State Department of Health during a period in 1917. Presumptive tests in lactose broth. Confirmatory tests consisted of Endo, secondary lactose broth, and agar slant.

The significance of the presumptive test has been complicated recently still further by the work of Hasseltine[1] who has pointed out the importance of such details as the sterilization of media, owing to the possible breaking down of the sugars in autoclave sterilization into monosaccharides, with consequent gas production by types other than B. coli. It is clear, therefore, that the various features of choice of media, period of incubation, sterilization, and of reaction must be considered of far more importance in any future standardization than has been the case in the past.

If we subscribe, in addition, to the assumption that gas formation is not a true index of the presence of B. coli, then a unified interpretation of quality approaches still more closely the mythical pot of

[1] Hasseltine, U. S. Public Health Service Reports, Vol. 32, No. 45, November 9. 1917.

TABLE 4

Methods used in various state department of health laboratories in confirming the presence of B. coli

NAME OF STATE	MEDIA USED																REMARKS
	Lactose broth	Lactose bile	Endo	Litmus lactose agar	Second lactose broth	Gelatine	Litmus milk	Dextrose broth	Indol test	Nitrate test	Dulcite	Gram stain	Agar slant	Motility	Russells' medium	Test for anaerobes	
California	+			+	+												
Connecticut	+		+		+								+				
District of Columbia		+	+														
Florida	+		+														
Georgia	+			+	+												
Illinois	+		+		+												Presumptive test in most instances
Indiana	+		+		+												
Iowa	+		+	+													Eosine-methylene-agar for experimental work
Kansas	+	+	+		+												Add. det. infrequently
Kentucky	+		+		+												
Maine		+		+	+												
Maryland	+		+		+												
Massachusetts	+			+													
Michigan	+			+	+												
Minnesota	+			+	+							+	+	+			
Missouri	+			+													
Montana	+			+	+	+											

New Hampshire		+															
New Jersey	+		+														Usually
New Jersey		+	+		+	+	+	+			+						Infrequently
New York			+	+	+	+	+		+	+							
North Carolina		+	+														
Ohio	+			+	+												
Oklahoma	+			+													
Pennsylvania				+				+	+								
Rhode Island	+			+													
South Carolina		+															
South Dakota	+			+	+	(Bile)						+		+	+		
Vermont				+													Also lactose neutral red
Virginia		+	+		+	(Bile)											
West Virginia	+																Public supplies
West Virginia	+			+	+										+	+	Private supplies
Wisconsin				+													
Wyoming	+		+														Also bile salt agar

NOTE: See note in table 1.

gold at the end of the "standard" rainbow. In fact, when subjected to the various discriminatory tests now available to the analyst, the much maligned bacillus coli seems to emulate the historic chameleon in all its possible forms. Table 4 indicates only slightly the variations in methods of confirming the presence of the B. coli in use in various state laboratories. This ubiquitous bacterium now poses either as the "survival of the fittest," after running the gamut of several sugar fermentations, gelatine, indol, nitrate, milk, and hydrogen-ion concentration determinations, at the hands of the city health commissioner, anxious to divert criticism from a water supply by seizing upon the "fecal type" of B. coli as his measure of quality; or else it assumes the shape of the simple initial lactose fractor serving as the proud exhibit of the fortunate filtration plant operator blessed with the excellent results of operation.

What shall the standard test for B. coli include, if a mere difference in the proportions of fuchsin and of sulphite in two Endo media, results[1] in the one showing typical colonies in 75 per cent of the tubes in which the B. coli is present, while the other shows the same colonies in only 14 per cent? Shall the lactose broth, to be used in the presumptive test, contain 0.5 or 1.0 per cent lactose,[2] if the latter is detrimental to the successful isolation of B. coli? Certainly, we dodge the issue somewhat if our standard vaguely demands, for example, that the "colon bacillus should be absent in 100 cc." Why the colon bacillus? How shall we know it? How often can it occur in 100 cc. without condemning the supply? These are questions which "standards" skillfully avoid answering.

In 1907, Phelps[3] discussed a method of estimating the numbers of B. coli from fermentation tube results. His system of numerical interpretation has served, until recently, as the basis of practically all quantitative estimates of B. coli in various waters. A misconception of the method proposed at that time has been responsible in a degree for the eternal cry for standardization. The realization of the fact[3] that "the method is obviously of no value for single tests and finds its most useful application in routine studies in water purification and sewage treatment extending over long periods of time" would tend to emphasize the utility, but uncertainty, of

[2] Levine, Notes on the Presumptive Test for B. coli. Engineering Exp. Sta., Ames, Iowa, 1917.

[3] Phelps, Method for Calculating Numbers of B. coli. *Jour. A. P. H. A.*, September 30. 1907.

fermentation tube results as usually obtained, as a basis for numerical interpretation. Granting the value of establishing a maximum allowable pollution of "x" B. coli per 100 cc., we are confronted still with the difficulty of estimating such numbers from the data afforded by our present bacteriological methods.

Greenwood and Yule[4] have indicated this difficulty in a remarkably clear manner, in the following passage:

> The fact that a given volume of water tested contains no bacilli or none which will grow, does not prove that the source of supply is sterile, the point is merely that the greater the volume tested with negative results the smaller is likely to be the population of organisms existing in the supply; none of the writers has attempted to provide a scale of bacterial densities corresponding to the increase of the minimum quantity of water found sterile on examination (not strictly true*). We think, indeed, that the tenor of the passages cited (referring to various standards*) creates a presumption that the authors' criterion really is that sources *shown by other methods or found from practical experience* to be safe or to be unsafe have *usually* been found to give sterile readings when samples of the assigned size have been tested. This would explain, for instance, the lower standard adopted in the case of moorland waters. This is undoubtedly a reasonable attitude of mind enough, but it is necessary to remark that the process is not wholly satisfactory, since two observers both testing the same source on, say, the basis of a sample of 100 cc. might obtain the one a positive, the other a negative result, so that one would reject, and the other pass the supply. Further, no criterion is provided of the increase in accuracy of prediction attained when two, three or more samples of 100 cc. all give sterile readings.
>
> * Notations by Morse and Wolman.

If the so-called B. coli index is to serve as the measure of the quality of a water supply, assuming that the technique of B. coli determination has been satisfactorily settled, the necessity still remains of determining the method of obtaining the index. The number of methods now available for determining the B. coli index introduces at once further complications. Shall a proposed standard embody the procedures of Phelps,[3] Greenwood and Yule,[4] McCrady,[5] Stein[6] or Wells?[7] The method of Phelps enjoys con-

[4] Greenwood and Yule, On the Statistical Interpretation of Some Bacteriological Methods Employed in Water Analysis. *Jour. of Hygiene,* July, 1917.

[5] McCrady, The Numerical Interpretation of Fermentation Tube Results. *Jour. of Infectious Diseases,* July, 1915, Vol. 17, No. 1.

[6] Stein, Making the B. Coli Test Tell More. *Eng. News. Rec.,* May 24, 1917.

[7] Wells, The Geometrical Mean as B. Coli Index. *Science,* January, 1917.

siderable popularity because of ease of application. Unfortunately agreement as to method has not always resulted in accuracy of application. In spite of the limitations discussed by Phelps, B. coli indices are calculated indiscriminately with few or many analytical results at hand. The fact that there may be three or three hundred results has generally no effect upon the use of the B. coli index in the hands of sanitary engineer, bacteriologist, or filtration plant operator. Twenty per cent positive in 1 cc. is used with the same significance whether as a result of five or five hundred samples. The further injunction that both positive and negative results should be obtained on limiting dilutions of water is treated, in a number of cases, with the same disregard for accuracy. One of the well-known filtration plants reports, for instance, a B. coli index of 0.7066 (number per cubic centimeter), from the following results: 100 per cent positive in 10 cc. and 67.4 per cent positive in 1 cc. No tests were made on 0.1 cc. samples, the note blithely stating that such tests were assumed to be zero. That such an abuse of the Phelps' method is not a rare occurrence is evidenced by the frequent repetition of such findings as the above. Standardization of quality would hardly obviate such statistical juggling as produced by another of the largest filtration plants in the United States, which reports a B. coli content of the filter effluent of 0.44 per cubic centimeter, based upon 77 per cent and 40 per cent positives in 10 and 1 cc. dilutions respectively. Here again the 0.1 cc. samples are naively placed in the negative column on the basis of a total of 13 tests, as against 314 in both 10 and 1 cc. dilutions. Aside from justifying the theoretical basis of the Phelps method, the further establishment of allowable numbers of B. coli in a water supply would demand far more restrictions upon its use and evaluation than are observed apparently by a number of water supply workers at the present writing.

Variations in the numerical interpretation of fermentation tube results have engaged recently the attention of analysts, with resulting surprising discrepancies in data obtained by different methods. These findings illustrate only too well the weakness of establishing standards upon such meager bases, as, for instance, the "absence of B. coli in 100 cc." Observation that 50 per cent of 0.1 cc. samples have given a positive test may be interpreted as indicating a source of supply containing a B. coli content differing by over 100 per cent, depending upon the method of quantitative determination employed.

Both McCrady and Stein would assign to the above result a bacterial content of 700 per 100 cc., Greenwood and Yule a value of 690, and Phelps a value of 500, while Wells would assume the probable existence of only 317. Even a result of +100, +10, −1, and −0.1 assumes a dual rôle depending upon the judgment of the interpreter, for the adherent to the "reciprocal of highest positive dilution" method would find a B. coli content of 10 per 100 cc., while advocates of several of the later procedures would support the probable existence of 23 per 100 cc. A mere difference of over 100 per cent! Table 5 is of interest in illustrating the varying possibilities of interpretation of the quality of a filter effluent, with no variation whatever in the fermentation tube results obtained under actual operating conditions.

TABLE 5

Influence of method of obtaining the number of B. coli from fermentation tube results upon the apparent quality of a water

FERMENTATION TUBE RESULTS POSITIVE TEST IN CUBIC CENTIMETERS			NUMBER OF B. COLI PER 100 CUBIC CENTIMETERS	
10	1.0	0.1	Phelps method	McCrady method
16/16	14/16		88.8	200
15/15	14/15		94.0	270
16/16	11/16		71.9	115
15/15	12/15		82.0	160
13/15	5/15		38.6	24
4/4	3/4		77.5	138
4/4	2/4		55.0	69
4/4	4/4	0/4	100.0	231
4/4	1/4	0/4	32.5	35
4/4	1/4	0/4	32.5	35
4/16	0/16		2.5	3
11/15	2/15		19.3	13
12/16	1/16		13.1	12
13/15	4/15		32.9	22
15/15	14/15		94.0	270
Average number per 100 cc..................			55.6	106

NOTE. Above fermentation tube results taken from operating records (1917) of a filtration plant in Maryland. The results were obtained on the filter effluent before disinfection.

Past standards for B. coli content have shown a surprisingly patent disregard of the importance of stipulating the necessary frequency of sampling of a source before its quality may be safely postulated. *In fact no standard comes to mind at the present time in*

TABLE 6

Number of samples necessary to establish a B. coli content to within the probable errors of 5 and 10 per cent

(From Stein, *Engineering News Record*, May 24, 1917)

PER CENT OF POSITIVE TESTS IN A SERIES	NUMBER OF SAMPLES TO ESTABLISH B. COLI PER CUBIC CENTIMETER TO PROBABLE ERROR OF	
	± 10 per cent	± 5 per cent
5	1900	7600
10	900	3600
15	760	3040
20	627	2508
25	485	1940
30	365	1460
35	320	1280
30	282	968
45	235	940
50	204	816
55	190	760
60	171	684
65	165	660
70	162	648
75	155	620
80	156	624
85	160	640
90	178	712
95	210	840

which the number of samples is apparently considered of sufficient importance to warrant even a cursory establishment of a necessary minimum. In certifying a public water supply to common carriers how many state departments of health insist upon a large series of samples before passing judgment upon the analytical findings? Some of these collect samples two or three or four times a year and then certify or do not certify on the bacterial content of some 500 cc. of water out of a total consumption of millions of gallons per year. It is useless to justify such procedure upon the score that neither time nor finances are available to health officials to follow

adequately, by frequent sampling, the condition of the supply. Infrequency of sampling, with consequent inaccuracy of interpretation, is not always recognized by sanitarians as dangerous. It is for this blindness to the invalidity of findings based on essentially variable phenomena and methods that "standards" are in a measure directly responsible.

Stein[6] has pointed out within the last year the extreme importance of an adequate number of tests before any relatively precise conclusions may be projected. Table 6 contains a portion of the data developed by Stein to show the number of samples necessary to establish varying B. coli contents to within a 5 or 10 per cent probable error. In the Treasury Department standard an allowable maximum pollution equivalent to 20 per cent of all tests positive in 10 cc. is fixed. Twenty per cent was chosen, it may be inferred, in the belief that such a series of results would be comparable with a density of 2 B. coli per 100 cc. in the water. It is highly disconcerting to learn that, in order to obtain even a fair degree of precision and an approximate approach to the above number of B. coli, something like 600 samples are necessary. How meager, then, is the analytical information afforded by even 10 samples a year and how ludicrous is the certification of a doubtful supply upon the basis of only two examinations a year.

One's sense of scientific precision, and even of scientific attitude, suffers a jar when attempting to correlate the quality of a water with the data furnished in a number of other types of investigations. The pollution of streams, for instance, is studied by some governmental agency. Extensive reports are written, conclusions are drawn, correlations between the B. coli content of the stream and other sanitary features are made, and recommendations ensue. But even some of these apparently excellent researches become of little value or even misleading when the data upon which they rest have been scrutinized.

Is a pseudo-scientific correlation between B. coli content and dissolved oxygen in a stream of any importance when the number of B. coli in the stream at different stations, is obtained from one, two, or three fermentation tests? Yet table 7 is a partial list of the data culled from a recent federal report which will illustrate the derivation of unwarranted conclusions concerning the bacterial content of a stream, based upon a small number of analytical results. We must certainly question a B. coli content of 0.47 per cubic centimeter, when this quantitative index to the sanitary condition of the stream has

been obtained from only three samples. In a number of instances, too, the dilutions were not carried out far enough to give a negative fermentation test. The table loses further scientific interest when in another column the total count on agar at 37°C. is given, for a particular station, an average value of 90, a maximum of 90, and a minimum of 90, all derived from a *single* sample. It is extremely doubtful whether even a standard of utopian character would suffice to eliminate such data as the above. Further study of the significance of data, rather than their standardization, would be desirable. Such procedures would result, perhaps, in the abolition of haphazard stream study with bacteriological samples aggregating, at the most, five per station. It should be pointed out, too, that the above criticism is directed not so much at the failure to maintain frequent sampling, but rather at the intensive use of such data for study and for recommendation.

TABLE 7

Frequency of sampling and the bacterial content of a stream at various stations

(From a recent federal report)

STREAM STATION	NUMBER OF SAMPLES	MEAN NUMBER OF B. COLI PER CUBIC CENTIMETER	TOTAL COUNT ON AGAR AT 37° C.		
			Average	High	Low
1	3	10.0	490	1160	40
2	3	46.8	630	1030	50
3	2	10.0	112	130	94
4	3	4.7	163	330	26
5	3	4.7	192	390	80
6	5	2.5	51	80	22
7	1	10.0	90	90	90
8	3	2.1	53	72	18
9	3	1.0	65	116	12
10	3	0.47	64	90	25
11	3	1.0	175	449	36
12	3	1.0	205	540	36
13	3	0.2	270	540	0

The method of making the B. coli examination of a single sample of water is capable of wide manipulation. The procedure in some laboratories usually consists in the inoculation of a series of fermentation tubes of different dilutions. The dilutions as a rule are in the usual geometric progression of 10, 1, 0.1, etc., cc. There does not

appear, however, to be any well-defined agreement among authorities as to the necessary number of fermentation tubes to be used at each dilution. The importance of using more than one tube at each dilution becomes manifest when it is borne in mind that Greenwood and Yule[4] have shown "that, if 'n' cc. have given a negative result, the chance of a second sample of 'n' cc. giving also a negative would be n/2n or 1/2." In other words, the chance of an inconsistency occurring when two tubes of the same dilution are used is no less than 1/2. It is clear, therefore, that too much emphasis cannot be placed upon the necessity of more than one tube at each dilution. It is of interest to note in this connection that some state department of health laboratories throughout the country recognize the value of numerous tubes, while others still use single tube determinations. Table 8 is a brief summary of the methods used in the laboratories and illustrates the wide possibility of interpretation of the quality of a supply, depending upon the laboratory in which the specimen happens to be examined. Certainly a sample of water examined in the laboratory of the State Department of Health of Connecticut may differ very materially in its supposed quality from a similar sample tested according to the methods in use in Michigan. It becomes extremely difficult, therefore, to compare types of water from different states upon the basis of percentage positive in different dilutions, when the details as to procedure are not given in complete form.

The effect of varying numbers of tubes can hardly be exaggerated, when the quality of a water is to be determined. Various refinements as to choice of numbers of tubes result very frequently in an improvement or degradation of the water in question, without any real difference in the colon content. A typical instance of such a procedure as the above is given by the method in use in a water filtration plant in Maryland. The laboratory at this plant determines the quality of its chlorinated filtered water by using a large number of fermentation tests in 10 cc., with a small number in 1 cc. In the month of June, 1917, for example, ten 10 cc., with only two or four 1 cc., samples were tested daily. The precision of results in 10 cc. was, therefore, something like twice that of the findings in 1 cc., since it varies as the square root of the number of samples. Such a system resulted in an unconscious placing of a premium on not finding B. coli in the lower dilution. Inasmuch as the quality of the chlorinated effluent, in this particular instance, was none too good, as indicated by the presumptive tests, it was distinctly advantageous, for a better

TABLE 8

Comparison of number of tubes used at each dilution in routine fermentation tests for B. coli in state department of health laboratories

NAME OF STATE	NUMBER OF TUBES USED IN DILUTION OF				
	10 cc.	5 cc.	1 cc.	0.1 cc.	0.01 cc.
California	2		2	2	
Connecticut	1		1	1	
District of Columbia	1	1	1	1	1
Florida	2		2	2	
Georgia	5		1		
Illinois	2		2	2	
Indiana	1		1	1	
Iowa	1 to 5		1 to 2		
Kentucky	1 to 5		1 to 5	1 to 5	
Maine	2		5		
Maryland	5		1 to 5	1	1
Massachusetts	1		1	1	
Michigan	7		7	7	
Missouri		1	5	3	
Montana			3 (2cc.)		
New Hampshire	3 to 5		1		
New Jersey					
Public supplies			5		
Private and new supplies			5	5	
Raw—highly polluted			2	2	2
New York	3		3	3	
North Carolina	1		1	1	
Ohio	1		2		
Rhode Island	1 to 2		1 to 2	1 to 2	
South Carolina	2		2	2	
South Dakota	3				
Vermont			1		
West Virginia	2		1		
Wyoming	2		2	2	

NOTE. See note in table 1.

showing of the plant, that the number of tubes should be reduced in the lower dilution. This was done, whether consciously or unconsciously is unimportant, with the consequence that during the month 232 tubes were used in the 10 cc. tests, while only 94 were employed in the 1 cc., or a ratio of precision in the two instances of approximately 1.6 to 1.0. The intensity of search for B. coli in the 1.0 cc. dilutions (the more important of the two under discussion) was therefore

materially reduced and the corresponding quality of the water probably enhanced. This was undoubtedly the case, since the proportion of positive tests in the 10 cc. was high (74 per cent) while in the 1 cc. it was only 7.4 per cent. It is somewhat hard to believe the data of a certain day when ten 10 cc. tubes were all found to be positive, while all of the four 1 cc. tests were negative. Here evidently the relative reduction of the number of tubes in 1 cc. from that in 10 cc. has created a less inferior quality of effluent to that probably existing. That the above conclusion is justified is inherent in the fact that, given a necessary predominance of possible negative over positive tests, or a low initial density of bacilli relative to the particular dilution, the smaller the number of total examinations the better the apparent quality of the water. In a small total number of tubes, the probability of the few possible positive tests appearing becomes very slight.

Chemical determinations. The importance of chemical examinations in determining the quality of a supply has been given considerable discussion in past years. The necessity for the so-called sanitary determinations has ranged from the viewpoint of the advocate of continuous and complete chemical analyses, as in Massachusetts, to the more radical exponents of the complete omission of sanitary chemical tests, as, for instance, the public health officials of Minnesota. The establishment of chemical standards for quality of water need not be gone into here in any detail, since both the methods and the accuracy of results in this field of water analysis are far more advanced than in the case of the bacterial tests. The problem in this instance, however, as well as in the case of bacterial standards, seems to lie more in the further study of the relative significance of data rather than in the establishment of meaningless standards based upon incomplete and variable manifestations of hidden phenomena.

Sanitary survey. Although the sanitary survey, or the study of the natural physical features surrounding a given water supply, has always been recognized as of prime importance in the consideration of the safety of a water, yet it has been rarely given the emphasis it necessarily demands in the establishment of arbitrary standards. It has been only recently that the United States Treasury Department has stipulated in its requirements that a sanitary survey of the sources of a supply should be included in the summary of the condition or quality of the water to be certified. Just what relative weight the field survey, as opposed to the bacteriological analysis, is given in the above system of standardization it is not possible to state. Pre-

cedent, too, has given far more consideration to the question of bacterial content than to any other extraneous features, with the result that, if the survey proves unsatisfactory, the layman and often the health officer of questionable honesty lay stress upon the more elusive and shadowy bacterial content. If a field survey indicates, for instance, that a water is subjected to filtration and disinfection under the guidance of the town plumber, with its attendant inconsistency of performance and continual hazard of unsuccessful purification, should or would such a survey preclude the issuance of a certificate, if the analytical data resulting from a few choice samples collected by the town authorities show the water to meet the "1/5 in 10 cc." requirement? It would seem that the artificial standard often serves the purpose of indicating the loophole through which the inefficient water company may escape, rather than of clarifying the situation as to doubtful quality.

That the general field survey has been given in the past by some sanitarians the attention it requires is undoubtedly true. Whittaker,[8] for instance, has pointed out within the last few months, as a result of a number of years of experience in Minnesota, that "the field survey and analytical results together should afford information on which recommendations can be made for the protection or abandonment of the supply." The standards of quality of water supplies should include, therefore, not only recommendations as to analytical data, but injunctions as to field or sanitary surveys. The establishment of standards as to "structural, environmental and operative features" would require,[8] in a greater degree even than similar attempts as to analytical work, an immediate standardization of method of survey rather than an evaluation of the results or findings of the survey. Here, as in the case of other possible quantitative water standards, the necessity indicates that the units of measure must be devised before the limitations of such units, as yet nonexistent, may be determined. It is the latter feature of the above axiomatic statement upon which most advocates of standards of quality lay particular stress.

PRESENT STANDARDS OF QUALITY OF WATER

State departments of health. The attitude of official sanitarians, such as those in charge of the activities of the various state depart-

[8] H. A. Whittaker, Fallacies in the Investigation of Water Supplies. *Jour. A. P. H. A.*, Vol. VII, No. 9.

ments of health, toward the advisability or necessity of the use or adoption of arbitrary standards of quality is reflected somewhat in the fact that Connecticut, Florida, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, South Dakota, Virginia and Wyoming use no arbitrary standard for interpretation, while California, Georgia, Michigan and Wisconsin use the United States Treasury Department standard or some variation thereof at some or all times. A number of the analysts and sanitary engineers expressed the opinion rather vehemently that no general standard could be devised to fit the peculiar conditions existing in that particular section of the country. Stephen De M. Gage, Chief of the Division of Chemistry and Sanitary Engineering of the Rhode Island State Board of Health, expresses[9] the situation with clarity in the following terms:

We do not use any arbitrary standard of quality of water. Each individual sample is judged upon its own merits, as shown not only by the bacterial examination but by result of the chemical tests and general knowledge of sanitary surroundings by inspection of the source. It is not practicable nor fair to attempt to apply any arbitrary standard of quality, bacterial or chemical, to New England waters.

It is interesting to note in all the correspondence with the various state departments of health that the United States Treasury standard is used in practically every instance in the certification of railroad water supplies, but in only 4 of the 24 is it applied generally to others. Opinions vary widely as to the desirability of adhering strictly to the bacterial limits given in the above standard. Frank Bachman, of the California State Board of Health, states[10] that

The Treasury Department's standards are too severe for municipal water supplies and that the 1 cc. standard used a few years ago was too low. Our arbitrary standard is between the two.

Edmon Greenfield, of the Illinois State Water Survey, agrees[11] somewhat with the above in expressing the opinion that

In many cases we consider the standards proposed by the United States Treasury Department for water to be used on interstate carriers as just and

[9] Stephen De M. Gage, By letter, dated November 21, 1917.
[10] Frank Bachman, By letter, dated December 3, 1917.
[11] Edmon Greenfield, By letter, dated November 13. 1917.

satisfactory. In other cases we do not feel that they apply as well as they might. The standard suggested by the United States Treasury Department for total count on agar at 37½° seems to be quite lenient, while the standard for minimum content of B. coli seems to be quite severe in some cases.

In Virginia, on the other hand, Dr. Fitzgerald, bacteriologist for the State Board of Health, assumes[12] a different attitude by pointing out that

> Our standards of quality vary from those of the Public Health Service, since we allow in certain samples a count of under 500. We classify samples showing colon bacilli in 1 cc. "bad," 10 cc. and 20 cc. "suspicious."

Bearing in mind the fact that the methods of arriving at bacterial results differ widely in the various laboratories and that the arbitrary standards, wherever they exist, are interpreted with considerable differences of opinion, we should not be very far astray in concluding that "standards of quality" are not entirely favorably viewed by most of the official sanitarians. That new and impracticable standards are not only undesirable, but almost impossible of establishment at this time, also seems to be the consensus of opinion of a large part of the analysts and sanitary engineers.

United States Treasury Department standard. The power of conjuring with the name of the federal government often leads to the adoption of procedures which, under unofficial stamp, would be subjected to closer scrutiny and to more suspicion. The bare requirements of the United States Treasury Department Standard have been accepted by many as a convenient, automatic, and almost mathematical means of determining the safety of an unknown supply. Given certain known quantities of water, a few bacteriological tests, the substitution of results in an equation, and the problem was solved. The standard is apparently definite, precise, and easy of application, but does it given an accurate index to the quality of a water supply? As usually carried out, the standard undoubtedly does not. It does not perform its function as quickly, as safely, as exactly as, even today, many health officials assume.

The federal requirements stipulate that

> The total number of bacteria developing on standard agar plates, incubated twenty-four hours at 37°C., shall not exceed 100 per cubic centimeter. Provided, that the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.

[12] Jas. O. Fitzgerald, By letter, dated November 13, 1917.

How reliable and accurate such estimates may be is made clear by the following abstracts from a discussion[13] by Prof. Geo. C. Whipple on "The Element of Chance in Sanitation."

The chance of a single bacteriological count exceeding a given standard of 100 when the actual number present in the sample is the figure given in the first column:

NUMBER OF BACTERIA PRESENT	CHANCE OF A SINGLE SAMPLE EXCEEDING THE STANDARD OF 100
100	1 in 2
90	1 in 2.8
80	1 in 5
70	1 in 12.5
60	1 in 66.6
50	1 in 2500

On the other hand, in a sample of water which contained more bacteria than the standard, there would have been a chance that the plate contained fewer bacteria than the standard.

NUMBER OF BACTERIA PRESENT	CHANCE OF A SINGLE SAMPLE BEING LESS THAN THE STANDARD OF 100
100	1 in 2
110	1 in 2.6
120	1 in 3.4
130	1 in 4.5
140	1 in 6.1
150	1 in 7.7
200	1 in 20.0

It will be seen from these figures that in the case of waters which contain fewer bacteria than the standard, but near it, the chance of a single count exceeding the standard is high but in samples which contain much fewer numbers than the standard the chance of a single count exceeding the standard decreases rapidly. In the case of samples which contain more bacteria than the standard the chance of a single count showing less than the standard is considerable. The chance of a bad sample being called good is greater than the chance of a good sample being called bad if the number of bacteria present differs greatly from the standard.

It is evident that when dependence is placed upon a single bacterial count a rigid application of the standard is likely to do injustice either on one side

[13] G. C. Whipple, The Element of Chance in Sanitation. *Jour. Franklin Institute*, August, 1916.

or the other. It is evident, therefore, that in order to prevent injustice being done in the application of quantitative bacteriological standards to water it is necessary that several tests should be made. The number of plates which should be made in any given case has not been definitely determined, but, obviously, a large number of plates should be made whenever there is reason to suspect that the water approaches a given standard in its bacterial content. For waters which are expected to be below the standard two plates would probably be sufficient, but under many conditions five or even ten plates may be necessary to give results which can be safely depended upon.

Since the number of samples and of plates vary considerably in different applications of the United States Treasury standard, it is entirely problematical what the significance of an allowable count of 100 is when the count may be obtained through the medium of one sample or several hundred during the year.

The second criterion of the federal requirement that "not more than one out of five 10 cc. portions of any sample examined shall show the presence of organisms of the B. coli group" leads one into further complications, when it is kept in mind that it was the intent of the standard to allow a possible maximum B. coli content of only 2 per 100 cc. The 1/5 in 10 cc. requirement was assumed to give a convenient method of testing the allowable "2 per 100 cc." content. How successfully it may succeed in doing this may be gathered from the following discussion[5] by McCrady.

Some calculations indicating the percentage of various results which will occur when various numbers of B. coli are contained in the sample, are shown below.

NUMBER OF B. COLI IN SAMPLE X	PERCENTAGE OF TIME THAT "0/5 IN 10 CC." WILL OCCUR	PERCENTAGE OF TIME THAT "1/5 IN 10 CC." WILL OCCUR	PERCENTAGE OF TIME THAT "2/5 IN 10 CC." WILL OCCUR
0	100.0	0	0
1	50.0	50.0	0
2	25.0	55.0	20
3	12.5	45.0	36
4	6.25	33.55	
5	3.13	23.26	
6	1.56	15.52	
7	0.78	10.09	
8	0.39	6.44	
9	0.19	4.05	
10		2.54	
11		1.57	

It will be noticed from these calculations that when 4 B. coli are present in the sample, the sample will pass the standard about 40 per cent of the time. And one out of about every six samples, containing 6 B. coli, will pass the standard (1.56 per cent plus 15.52 per cent). On the other hand, one out of every five samples containing only 2 B. coli per 100 cc. will fail to pass the standard.

Consequently, when it is remembered that the standard signifies a most probable limit of 2 B. coli per 100 cc., it is evident that the standard method of analysis renders the standard much more lenient than might, at first glance, be supposed.

The above discussions illustrate the possible defects of the Treasury Department standard when the requirements are literally followed. Since no complete directions are given as to method, frequency of sampling, or interpretation of the analytical procedures outlined, the possible variations in significance of the standard become manifest. The standard becomes, therefore, not a precise and accurate index as to quality, but rather simply a convenient mode of analysis to be used with considerable caution for comparative purposes.

A rather curious abuse of the federal standard has resulted in recent years from the failure of the requirement to specify the exact and relative importance of the somewhat "delphic utterance" that "it is recommended, as a routine procedure, that in addition to five 10 cc. portions, one 1 cc. portion, and one 0.1 cc. portion of each sample examined be planted in a lactose peptone broth fermentation tube, in order to demonstrate more fully the extent of pollution in grossly polluted samples." Inasmuch as the requirements suggest the 1 and 0.1 cc. tests, but make no stipulation as to their relative significance, it becomes extremely convenient for health authorities, water companies and filtration plant operators to discard the lower dilutions whenever the results in 10 cc. meet their purposes better. It should be borne in mind that unfortunately the aim of some who operate water supplies is not always to determine the real quality of the supply, but to defend it, in the face of criticism, by endeavoring to show, through judicious selection of data, that the water passes the standard of the United States Treasury Department.

A striking illustration of such a procedure is given by the situation in one of the cities in Maryland. The municipal supply is not always of the best and controversial discussion as to quality has occurred from time to time between state and municipal health authorities. The question of certifying to the supply is still a source of disagreement, simply because of the vagueness of the federal requirements.

A municipal official may insist upon the selection of a short series of good results that may have occurred just prior to the date for certification, when these results are not typical of those obtained during the rest of the year, or upon the strict application of the 10 cc. criterion, in the face of contradictory evidence given by lower dilutions. A discussion of the data shown in table 9 will make the situation clearer. In this table there have been collected the results of labora-

TABLE 9

Significance of 1.0 and 0.1 cc. dilutions in determining the quality of a supply by the United States Treasury Department standard

1917 MONTH	B. COLI PER CENT POSITIVE CONFIRMED IN			B. COLI PER 100 CC. (BY PHELPS' METHOD)
	10 cc.	1 cc.	0.1 cc.	
January	20.5	6.4	0.6	13.21
February	61.9	26.5	6.2	
March	26.3	9.0	3.2	39.53
April	16.7	3.6	1.4	17.51
May	26.7	9.3	0.7	17.34
June	33.3	15.1	2.4	38.52
July	26.8	15.7	6.3	73.51
August	26.0	12.0	2.0	31.40
September	39.0	10.0	1.0	21.90
October	18.0	2.1	0.0	3.69
November	24.3	0.0	0.9	11.43
December	9.9	2.0	0.0	2.79

Average B. coli index, from 10 cc. results only = 2.43 per 100 cc. (exclusive of February).

Average B. coli index from 10, 1 and 0.1 cc. dilutions = 24.62 per 100 cc. (exclusive of February).

NOTE. Above results obtained from tap water analyses in city in Maryland. Average number of samples approximately 125 per month.

tory examinations extending over the year 1917. By averaging only the 10 cc. results for the year and estimating from these the number of B. coli per 100 cc. (by Phelps' method), we obtain an average B. coli content of 2.43 per 100 cc. This value is somewhere near the maximum allowable density usually assumed as the requirement of the Treasury Department. When using the additional results of 1 and 0.1 cc. dilutions, the quality of the water takes on an entirely different aspect. The average number of B. coli per 100 cc. (also calculated by Phelps' method) now becomes 24.62, or over ten times

the value obtained from the 10 cc. dilutions alone. The city health official would support his contention as to certifiability upon the 10 cc. basis while ignoring the much less attractive 1 and 0.1 cc. results.

In the month of April, for instance, the water, on the basis of the 10 cc. figure, would meet the certification requirement. Yet, by using all the data available, the B. coli content of the water may be assumed to be 17.51 per 100 cc. If the 1 and 0.1 cc. dilutions had not been made, as is often the case, the doubt as to the superior quality of the supply would have been removed, in spite of the fact that the water contained approximately nine times as many B. coli as is tacitly allowed by the federal requirements.

The above data and their application are not at all hypothetical, but are exact and accurate duplicates of conditions which have occurred in Maryland, and probably in other states, as a result of the compulsory adoption of exact standards and their adaptation to variable phenomena. In such instances, the application of the standard aids the official to dodge the responsibility of producing water of excellent quality, instead of serving as the means of detecting poor quality.

It is well to point out, before leaving the discussion on the federal standard, that, if any changes are contemplated in its requirements, emphasis must be placed upon the necessity of using all the data extending over the periods intermediate between the official certification dates, rather than a few choice samples collected just prior thereto. Too often a large series of earlier results are discarded for more convenient later data. It comes about, therefore, that the present federal requirement may assume a two-fold aspect depending upon the whim of the water supply administrator. Incidentally, haphazard certification to the Treasury Department by local health officials, who are frequently over-zealous, should be stopped and this duty delegated only to the state health organizations.

Filtration plants. The analytical methods in use at the various filtration plants throughout the country have been made the subject of an extensive and detailed compilation within recent months by Jack J. Hinman, Jr., of the Iowa State Board of Health. Mr. Hinman has gathered such complete data on this subject that it would be entirely unnecessary to discuss here the procedures further than to quote from one of his discussions[14] the following words:

[14] J. J. Hinman, Jr., Water Works Laboratories. *Iowa Academy of Science*, Vol. xxiv, 1917.

A glance at the table will show you that in spite of the excellent work which has been done in the preparation of our Standard Methods of Water Analysis, the bacteriological procedure of the water plants is far from uniform.

It seems, therefore, that the possibilities of obtaining definite units of measure of quality for filter plant effluents are as remote as those for general water supplies.

It is of passing interest to note at this point several deleterious effects of the past standardization of filter effluents upon an accurate interpretation of quality. One of the oldest methods of rating filtration plant performance, in reality sometimes resulting only in a specious attempt to conceal by circuitous methods the quality of an effluent, is the familiar "percentage efficiency" method. Its basis, its shortcomings, its dangers, even today, have been elaborated time and again, but the "percentage efficiency" still persists as the old "war horse" blinder for inefficiency and poor effluent.

Attention is called here only briefly to another practice which has come to the author's attention in the use of the above method, resulting in an added objection to the formation of reckless standards which years do not serve to obliterate from the minds of the gullible public. The average percentage removal of bacteria during a particular month means to most laymen the usual or mean removal effected during individual days. If this average figure happens to reach 98, then all is well in the heart of the consumer, if not in the mind of the health officer. If this method of standardization is to be used, its mathematical evaluation should be, at least, properly developed. Strange as it may seem, the practice has persisted in two of the filtration plants in Maryland of summing up the total raw water and effluent bacteria for the month and calculating from these totals the average monthly percentage removal. This resulted, for example, for one step of the purification process, in a figure of 77.0 during a month in which more than 40 per cent of the days show a percentage removal of 47 or under, while at no time during the month did the removal exceed 93 per cent.

The obvious effect of calculating average percentage removals by means of total bacteria for the month is to vitiate the poor results of many days by good results on a few. The ordinary and real operating results of the plant are totally lost sight of. This effect is made clear by the following series of results from the plant under discussion

June 18–23, bacterial removal, coagulating basins to filter effluent

DAY OF MONTH	AVERAGE COUNT, 20°C.		PER CENT REMOVAL
	Coagulating basin effluent	Filter effluent (Unchlorinated)	
June 18............	1355	160	88
June 19............	295	210	29
June 20............	135	85	37
June 21............	1280	146	89
June 22............	130	124	5
June 23............	285	180	37
Totals...........	3480	905	285

Average percentage removal—by Method (a), 74.0
by Method (b), 47.5

The percentage removal designated (a) is the value obtained by the method in use at the plant, consisting of the percentage change in the total numbers of bacteria for the week. This value is recorded, then, as the average percentage removal, in spite of the fact that on four days out of the six the performance was nowhere near 74.0 per cent. It is manifest from the above data that two excessively high basin counts hide completely, in method (a), the poor results obtained during two-thirds of the week. The undue influence of a few high raw water counts is accentuated, due to the fact that they are almost always accompanied by high percentage removals (for instance, June 18 and 21). A few days, or even one day, of high raw water counts may predetermine the value of the percentage removal for a whole month. Table 10 is exhibited in this connection, since it illustrates the possibilities of statistical juggling even with such an apparently stable and uniform procedure as the calculation of percentage removal. In explanation, it should be pointed out that method (b) consisted of obtaining the average of the *daily percentage removals* (as stipulated in the report of the committee of the New England Water Works Association, January 13, 1915) rather than the percentage removal of the total raw water and effluent bacteria. In a discussion of the average performance of a plant, the individual daily performances are dealt with, since the *performance*, not the bacteria, is under scrutiny.

The above discussion illustrates the abuses to which a standard or unit of measure may be subjected when the mode of determining

the unit has not been defined in iron-clad terms; and, secondly, it illustrates a fallacy which has not always been kept clearly before us, that is, that a measure of performance, whatever its method of

TABLE 10

Comparison between average percentage removals obtained by two different methods of calculation

MONTH		PERCENTAGE REMOVAL						
		Turbidity			Bacteria at 20° C.			
		Basin 1	Basin 2	Filters	Basin 1	Basin 2	Filters	Chlorine
January	Reported	73.5	76.0	94.5	75.0	77.0	94.5	93.0
	Revised	50.0	53.0	95.5	53.0	48.0	93.8	90.5
March	Reported	89.5	90.5	96.7	86.0	87.0	75.0	97.0
	Revised	77.2	80.4	97.7	80.0	83.0	71.7	95.6
April	Reported	79.0	79.0	100.0	84.5	82.5	88.5	91.0
	Revised	76.2	77.1	100.0	78.0	71.2	88.8	73.3
May	Reported	78.0	79.0	100.0	71.0	61.0	66.0	92.0
	Revised	76.3	77.4	100.0	70.0	53.0	57.0	66.0
June	Reported	87.0	98.0	98.5	88.0	86.0	80.0	71.0
	Revised	76.0	78.1	98.1	74.7	73.0	67.8	63.2
July	Reported	89.0	92.0	100.0	84.0	82.0	69.0	78.0
	Revised	77.9	81.7	99.3	64.0	60.9	64.0	52.0
August	Reported	71.0	73.0	96.0	59.0	37.0	62.0	93.0
	Revised	69.4	67.3	97.3	42.3	21.0	54.5	86.5

NOTE. *Reported* results calculated by Method (a)—see text.
Revised results calculated by Method (b)—see text.
Reported results taken from records of a filtration plant in Maryland. The percentages are calculated for successive steps of the purification process.

calculation, is not synonymous with a measure of the quality of an effluent. It may frequently happen that the unit of performance may be so chosen as to give an index to the quality of the effluent, but the same objections cannot be raised to standards of performance as to those of quality. In the former, comparative data may always be used in the study of the functioning of a plant, regardless

of their peculiar significance, but in the latter, the significance of absolute, and not relative, values is to be considered.

SUMMARY

The establishment of a standard of quality for potable water means the setting up by some accepted authority of a rule for the measure of quality. Since quality is a variable attribute, intricately dependent upon a series of natural physical, chemical and biological phenomena, its measurement becomes extremely difficult. The quality of a particular water cannot, in most instances, be measured adequately by means of the evaluation of only one of its characteristics. The real consideration or interpretation of the potability of a supply involves a series of mutually active attributes, each of which plays a part of importance in modifying and determining the character of the water. Any scientific and practical standard must include, therefore, a composite of all those features which influence a change in quality. The single ultimate unit of measure or the final standard becomes, in this way, an index number of properly weighted individual and fundamental units.

The prime requisites for the establishment of any standard are the existence of those basic units which are to be its components and of universal agreement as to the relative significance of such components. In the field of water supply neither of the two above requirements has been fully met. Basic or fundamental units for measurement of quality have not been established with any degree of exactness or accuracy. A unit of measure, such as the B. coli content, certainly cannot be predicated upon such variable procedures as are now followed, without resulting in a confusion of interpretation. The establishment of any unit demands an absolute consistency in its measurement. It is this consistency of measurement which is now absent in practically every available measure of quality.

If inconsistency reigns in the determination of the fundamental units, such as the total count, the B. coli content, the chemical constituents and the sanitary survey, then the general standard of quality, a derived unit composed of basic measures, becomes of extremely little value. If we add to this consideration of inconsistent method of obtaining individual units the fact that their relative significance is still unsettled, then a general standard becomes practically useless and even misleading.

From the above discussion, it becomes clear that the study of the *method* of evaluating a unit must of necessity antedate the attempt to establish *limiting values* of such a unit. A critical survey of past standards of quality seems to indicate an assumption that the method of unit-evaluation is fixed, and therefore that limiting values are the desiderata. It is not felt that the status of laboratory or field method of analytical examination warrants any such assumption. The field for future standardization of quality of water supplies would appear to lie more immediately in the consideration of such problems as the relative significance of different bacterial counts, the methods of obtaining the counts, the necessary frequency of sampling, of plating, of numbers of fermentation tubes, the numerical interpretation of usual fermentation tube results, the allowable variations from specified bacterial contents, the determination of real bacterial indices to sewage pollution, the importance of chemical determinations, and the standardization of field survey method. More remotely, the problem of standards is concerned with the coördination of the results of such studies as the above in such a way as to construct a composite unit of measure. Until these studies have been made and a general agreement reached, a standard would have but little value.

WATER SUPPLY AND SANITATION AT GOVERNMENT CAMPS AND SHIPYARDS[1]

By Samuel A. Greeley

The author has been connected during the past year with sanitary work for the Government in three different capacities, first, for cantonment construction; second, for the Public Health Service, and third for the Emergency Fleet Corporation.

It has been interesting to see the extent of this activity and the amount of work that is being done.

The water works, sewerage system and other utilities at Camp Custer are in charge of Major T. A. Leisen, President of the American Water Works Association. The author was there in the first part of January when an interesting phase of the work was the water consumption. The consumption on which the design of the system at each cantonment was based was 55 gallons per capita per day. Camp Custer was using 60 to 65 gallons at the time of the author's last visit. From 45 to 75 gallons is the range at the cantonments of which the author has records, and there is a tendency to increase rather than decrease the amount. Some of the cantonments have sewage treatment plants and these are being operated with great care; so much so that the author feels that the field of sewage works operation will receive an impetus from the results obtained in the operation of the cantonment plants. Officials in charge of them compare notes and thus gain by the combined experience of the operators at all camps.

The United States Public Health Service is an old organization which has recently expanded its sanitary division, which is now very well fitted to take up the work of sanitation in the cantonment zones. Where the Government has built large cantonments, it has established zones around them and has taken charge of the sanitary activities within those zones. The zone in Louisville is perhaps the most important because one of the army cantonments touches the city, which thus comes within the cantonment zone.

[1] Read before the Illinois Section at Urbana, April 16, 1918.

The Public Health Service sent two men of medical training to Louisville in October, about the time the troops began to arrive there. They established themselves on a coöperative working basis with the city and county health officers. They got things done that had been talked about as being necessary for many years. They actually built over 500 sanitary privies within a few miles of Camp Zachary Taylor. Almost every farm was fitted with a flyproof sanitary privy. In addition, they took up the restaurant question and the physical examination of employees in restaurant kitchens.

The author had been working on the garbage and refuse disposal problem in Louisville during 1917, and at the time the Public Health Service stepped into the work there, things were nearly ready to develop into some action. A beginning had been made on ordinances to organize a collection department, to improve conditions on the dumps and to provide for garbage disposal. The Public Health Service obtained a man who was familiar with the town and put him in charge of the collection work. Now they are subdividing the town into districts and establishing a model collection service in different parts of the city, with the idea that the city will extend this service over the whole city. The program calls for the separation of ashes and rubbish from the garbage. From the districts, ashes and rubbish are taken to a dump, which is run as a model. A part of the garbage is taken to a hog farm, also under the supervision of the Public Health Officers, and a part to a rendering plant. They are thus doing work that will be of permanent value to Louisville and of much value to other communities.

For ship construction under the Emergency Fleet Corporation the country is divided into eleven districts, extending along the Atlantic, the Pacific, the Gulf and the Great Lakes. Last November the Department of Health and Sanitation was established under the direction of Lieutenant-Colonel P. S. Doane. He contemplates, as soon as he can, placing a sanitary engineer in each of these shipping districts. The work has the following three objects:

1. The actual condition of the yards, to see that there is nothing which may create sickness among the men.

2. The environment and conditions; to see that health conditions in the towns where the men live are good.

3. To see what the local and state health departments are doing and where they can be assisted.

The work taken up by this Department of Health is first medical and concerns accidents. It promotes the establishment of small hospitals and dressing rooms, with nurses and doctors in attendance. In some yards there are physical examinations of the men to see that they are not likely to bring disease into the yard. Cases of illness are followed into the homes, to be certain they are handled as wisely as possible.

The next thing is sanitation, and the methods can be best explained by examples of conditions in some of the western yards. In Washington, Oregon and California there are about 50 shipyards. In Washington and Oregon there has been a tremendous increase in the lumber activities. Many towns in these states have gone as far as 25 miles distant to get their water supplies. They now find themselves suddenly faced with the danger resulting from camps of 400 to 500 men on the drainage areas, which are very likely to make trouble with their water supplies. In some of the yards of California, the mosquito problem is very important. In the yards near the city of Los Angeles last summer it was necessary to maintain smudges to keep off the mosquitoes. Work has already been started on that problem. We find many instances where the Federal Government, in its effort to maintain healthful conditions at the shipping yards, can coöperate with the local authorities. In some parts of the West where fishing is carried on extensively, there is a great fly problem and flies are not only thick enough to be a nuisance, but in the restaurants and eating places a real danger. Many of the ship yards located at a considerable distance from restaurants, have had to furnish their own lunch rooms and some of them have not yet developed their sanitary systems sufficiently to meet the fly problem.

The department of health and sanitation goes into the matter of housing. It does not have jurisdiction over additional new houses but takes up the question of sanitation in existing houses. For instance near some of the large works in San Francisco the lodging houses near the ship yards are not properly maintained and the men can not get proper lunches. The city and state departments of health feel that with the coöperation of the Emergency Fleet Corporation improvements of a permanent nature can be accomplished. The question of light and heat also comes into the field of the department of health and sanitation.

SANITARY ASPECT OF THE WATER SUPPLIES AT THE ARMY CANTONMENTS[1]

By Lieutenant-Colonel James T. B. Bowles, N.A.

One of the duties of the Sanitary Corps has been the supervision of the quality of water supplies at the various cantonments.

The water requirements of the cantonments, both from the standpoint of quality and quantity, have been anticipated by the Cantonment Division of the Quartermaster Corps remarkably well. No source has been so inadequate that there was such danger of shortage that it had to be supplemented by additional sources;—no source was questionable from the sanitary standpoint to the extent that its use was prejudicial to health.

In the development of the water supplies, purity was not lost sight of. Construction Quartermasters at the various cantonments were given blanket authority to purchase chlorinators. This was done in practically all cases, either one or more chlorinators being installed.

The development of supplies for the cantonments has been along the following lines:

(a) Purchase of water from municipalities where the camp was located within a reasonable distance from city and where the municipal plant had facilities to assume the additional load.

(b) Development of a special supply,—a ground water supply where there was knowledge of water bearing strata, and where the cost of obtaining it was not prohibitive.

(c) Lastly, development of surface supplies, supplemented by a purification process where necessary.

Of 31 National Army and National Guard camps, 18 are supplied with water from municipal systems. Twelve of these are surface

[1] "Permission to publish the inclosed article, entitled 'Sanitary Aspect of the Water Supplies at the Army Cantonments,' by Lieutenant Colonel James T. B. Bowles, is granted as requested.

"By direction of the Surgeon General:

James W. Van Dusen,
Colonel, Medical Corps, N.A."

Presented at the annual convention at St. Louis, May, 1918

supplies, demanding such purification as will insure at all times a clear, colorless and sanitary water. Six are ground waters, requiring no purification, with possible exception of chlorination more as a prophylactic than a necessity. Most of these municipal systems have been found amply large enough to assume the demands of additional consumption without increased plant development.

Fourteen supplies were developed by the Cantonment Division; only three of these were surface supplies.

One of these surface supplies utilizes water from a sparsely inhabited water shed, and as a sanitary precaution no other purification is necessary than chlorination. The other two are from polluted streams and require purification.

Of the ground water supplies developed, none required purification other than chlorination.

In the case of the western camps, where ground waters are used, softening for boiler and laundry purposes has been considered advantageous.

Supervision of quality of water has been conducted on the following lines:

(a) Inspection of municipal plants.

(b) Arrangements whereby frequent bacteriological examinations of all sources could be made.

The inspection of municipal plants revealed many interesting conditions. In many cases a modern up-to-date plant, supervised by live officials with a sense of the necessity of pure and wholesome water; but in too many cases, plants operating with a low margin of safety, and under the control of operators who had little knowledge of the kind of water the plant was turning out.

The inspection resulted in either assisting the city to secure competent men to supervise operation or to make arrangements whereby an officer of the Sanitary Corps would assume responsibility for the quality of the water.

Some authorities gladly and willingly coöperated in carrying out the improvements and changes recommended. Others reluctantly admitted that the quality of their water supply was not above suspicion. This latter class was usually the short-visioned, non-informed type of citizen, whose ideal of the best fulfillment of his position was in keeping a tight clutch on the purse-strings.

From the beginning of the cantonment activities, an effort was made to secure accurate bacteriological data concerning the various

Water supplies at national guard camps

Camp	Municipal supply	Developed by cantonment division	Character			Purification process							Remarks
			Ground water	Surface water		Plain sedimentation	Chemical treatment	Coagulation	Filtration		Chlorination		
				Impounding reservoir	River				Pressure filters	Mechanical gravity	Liquid chlorine	Hypochlorite	
Beauregard		yes	yes										
Bowie	yes			yes*			yes	yes		yes	yes		* West Fork, Trinity River. Water slightly hard at times. Considerable turbidity
Cody	yes		yes										Unquestionable purity. Fairly hard. Artesian wells
Doniphan	yes			yes*			yes[1]				yes		* Lake Lawtonka. Trouble from heavy algal growths
Greene	yes				yes	yes	yes	yes		yes	yes		Catawba River. Soft water. Considerable turbidity at times
Hancock	yes				yes	yes	yes[2]			yes	yes		Savannah River. Soft water. High turbidity at times
Kearny[3]	yes				yes	yes	yes		yes		yes		San Diego River. Soft water, slightly colored, variable turbidity
Logan		yes	yes										
McArthur	yes		¾		¼*		yes	yes		yes	yes		* Brazos River. Treatment applies to river water only

McClellan......	yes		yes										
Sevier.........	yes			yes*			yes[4]		yes		yes		* Source, mountain springs.
Shelby.........		yes	yes										
Sheridan.......	yes		yes*										* Artesian wells
Wadsworth.....	yes		yes			yes	yes	yes		yes	yes		
Wheeler......		yes[5]			yes*		yes		yes		yes		* Stone creek
	yes				yes*		yes	yes		yes	yes[6]	yes	* Ocmulgee River

[1] Copper sulphate twice monthly.
[2] Alum applied to water entering sedimentation basins, during high turbidity.
[3] Artesian wells in River Bed, used as emergency supply.
[4] About one-third of water from an isolated reservoir, treated with alum and passed through pressure filters.
[5] An emergency supply and used until camp had been connected to city mains.
[6] City water is chlorinated before entering camp distribution system.

Water supplies at national army camps

NAME OF CAMP	MUNICIPAL SUPPLY	DEVELOPED BY CANTONMENT DIVISION	CHARACTER OF SUPPLY			PURIFICATION PROCESS							REMARKS
			Ground water	Snrface water		Plain sedimentation	Chemical treatment	Coagulation	Filtration		Chlorination		
				Impounding reservoir	River				Pressure filters	Mechanical gravity	Liquid chlorine	Hypochlorite	
Custer.........		yes	yes				yes[1]				yes		A relatively hard water, 250 p.p.m. $CaCO_3$. Unquestionable purity
Devens........		yes	yes									yes[2]	Water has been exceptionally good despite evidences of pollution
Dix............		yes			yes*						yes		* Rancocas Creek. Highly colored, high free CO_2 free vegetable acid in small amounts
Dodge.........		yes	yes								yes		A hard water. Original purity unquestionable
Funston.......		yes	yes								yes		A relatively hard water
Gordon.......	yes				yes*	yes	yes[5]	yes	yes		yes		* Chattahoochee River. A soft water highly turbid at times
Grant........		yes	yes								yes		A hard water. All boiler water softened
Jackson....	yes				yes*	yes	yes[5]	yes		yes	yes		* Congaree River. A soft water, highly turbid at times. Polluted
Lee............	yes				yes*	yes	yes[5]	yes		yes	yes		* Appomattox River. A soft water, highly turbid at times. Polluted

Lewis..........		yes	yes										
Meade.........		yes			yes*		yes[5]	yes		yes	yes		* Little Patuxent River. A soft water. High turbidity, varying with rainfall. Relatively polluted
Pike...........	yes				yes[3]*	yes	yes[6]	yes	yes[4]			yes	* Arkansas River. A very turbid water, and relatively hard at times. Polluted
Sherman.......		yes	yes								yes		
Taylor.........	yes				yes*	yes	yes[5]	yes		yes	yes		* Ohio River. A soft water, highly turbid at times. Polluted
Travis.........	yes		yes								yes		
Upton.........		yes	yes										

[1] Water for all heating systems and laundry softened.
[2] For emergency use. During winter several breaks occurred in well casing.
[3] Artesian well water used when chlorine in river water goes above 400 p p.m.
[4] About four-fifths of the plant is pressure filters.
[5] Alum and lime treatment.
[6] Iron and lime treatment.

supplies. Prior to any definite knowledge of the potability of these supplies, it was assumed that they were all more or less polluted, or at least there was potential pollution and facilities for chlorination were installed.

In this the department had the coöperation of the manufacturers of the apparatus for applying liquid chlorine, who gave prior consideration to all Government orders. Analyses were made at the Army Medical School, Washington, D. C., and the Departmental Laboratories of the U. S. A.; by the Red Cross Units and the Public Health Service, and at the base hospital laboratories connected with the various camp hospitals.

In the early period of the camps, semi-weekly samples were collected and forwarded by express or mail to the nearest Government laboratory. Where the results of the analyses showed contamination, the camps were immediately informed by telegraph. The means of protection was chlorination, and where this was not possible an order was issued to boil all drinking water.

In the extra-cantonment areas, the U. S. Public Health Service included examination of water supplies in their routine work. This was of great assistance in checking up the operation of municipal supplies. A great many of these municipalities had no analytical data on their water supplies; furthermore there seemed to be no tendency on the part of the various State Boards of Health to exercise supervision or control. Where analytical data were available the interpretation corresponded to numerous and varied standards.

The standard of the Treasury Department as applied to interstate carriers was early adopted as the standard of water supplied to the cantonments.

In the early period of the camps, considerable apprehension was caused by the results of the analytical tests, which in many cases indicated gross pollution. This could be accounted for only as a result of construction. This pollution was in most cases temporary and gradually disappeared with continued use of wells and distribution systems.

Since the base hospital laboratories have been equipped, bacteriological analyses of water are now a part of the daily routine.

The results of sanitary water and typhoid prophylaxis have resulted in a remarkably small number of cases of typhoid and related diseases among the troops at the camps. From September 14 to

April 26, there have been 123 cases of typhoid with seven deaths, 315 cases of dysentery with one death.

What quota of these cases is attributable to water it is impossible to say.

Several of the typhoid cases developed in the early part of September and may have had their origin in civilian communities.

In conclusion the author would state that liberal application of chlorine, with close laboratory control and supervision, has resulted in a pure and wholesome water being supplied to the camps at all times.

LOSS OF HEAD IN CORPORATION COCKS AND SERVICE PIPES[1]

By Bernard J. Bleistein

Several years ago a series of tests was made by the Bureau of Investigation and Design of the Department of Water Supply, Gas and Electricity, New York City, to determine the losses of head in corporation or service cocks and service pipes. The results of these tests may prove of value to the water works profession, particularly the tests of corporation cocks, there being very little data available on that subject. All sizes in use by the department at that time were tested. Of the two largest sizes four of each type were tested and of the smaller sizes, two of each type. Of the lead and galvanized service pipes four lengths of each size about 15 feet long were tested.

The observations were very carefully made, the losses being measured by mercury deflections, and the discharges by a 2-inch meter of the current type. This type was selected rather than a meter of the disc type, as the flow through the latter caused considerably more vibration and fluctuations of the mercury deflections than a meter of the current type. The same meter was used during the entire series. It was rated on a testing machine at the beginning and end of the tests, the exact discharge at the various rates being determined by weighing.

The corporation cocks were inserted in a length of 12-inch cast iron pipe, capped and plugged at the ends, by a tapping machine in the usual manner. The main was connected to a fire hydrant through the plugged end by means of a short piece of 4-inch galvanized iron pipe. The cocks were set about a foot apart, the 2-inch cocks being set nearest the capped end of the pipe in order to eliminate any uncertainties due to swirls at the high rates of flow.

New lead pipe of a size corresponding to the size of the corporation cock and of double A weight was connected to the tail piece with the

[1] Read before the St. Louis Convention, May 16, 1918.

usual form of wiped joint. The meter with a control valve at the outlet end was connected to the other end of the lead pipe. The galvanized pipe was connected in a similar manner. Both the lead and the galvanized iron pipe were of the usual commercial sizes, the galvanized being of standard weight. The lengths were selected at random from a large stock. The lead pipe was handled more carefully than such pipe is usually handled in order to prevent denting or needless bending of the pipe.

In measuring the losses through the corporation cocks, a U-tube partly filled with mercury was used. One leg was connected by means of rubber tubing to a $\frac{1}{4}$-inch opening in the top of the main, and the other to a $\frac{1}{16}$-inch opening in the wall of the lead pipe one foot from the end of the tail piece. The rubber tubing and the upper half of the U-tube were completely filled with water. The loss measured included the velocity head, entrance head, and the frictional losses through the cock and 1 foot of lead pipe. This total loss was high, and at the high rates of flow it was necessary to connect three tubes in series, the loss being the sum of the deflections in each tube.

The losses in the pipe were measured in a similar manner, the two legs of the U-tube being connected to $\frac{1}{16}$-inch openings, 2 and 4 feet apart. Tee connections were provided at the different openings and it was thus possible to measure the losses in the corporation cock and the various sections of each length simultaneously. The sum of the losses in the various sections was used in computing the unit loss for each length.

Some difficulty was experienced at first in preventing the formation of a burr on the inside surface of the lead pipe in drilling the holes through which the pressures were transmitted. This was finally overcome by punching the holes through the walls from the inside in the following manner: Two $\frac{1}{8}$-inch holes were drilled partly through the walls of the pipe on points diametrically opposite, and one of them continued as a $\frac{1}{16}$-inch through the wall. By inserting a piece of solid drill rod through this opening, the opposite wall was punched through, leaving the inside surface quite smooth. The burr around the inside of the drilled hole was removed as much as possible with a special tool, and the hole plugged up and soldered. After the tests were completed, the pipe was cut open at each of the holes and the inside surface examined. In only two cases was a burr found and in both it was very slight.

A single $\frac{1}{16}$-inch hole was drilled through the wall of the galvanized iron pipe at each pressure point, using a high speed drill. A small burr was formed but no attempt was made to remove it, it being felt that this burr would not affect the results materially as the inside surface was already quite rough.

In taking the readings three observers were used, one to read the meter, the others to note the U-tube deflections. At each rate of flow a sufficient quantity of water was allowed to pass so that the dial hand on the meter made a complete revolution. In this way any errors due to eccentricities of the dial hand or inaccuracies in the graduations were eliminated. The time was taken with an ordinary watch, readings being taken to the nearest half second. As the total time for any individual test was never less than two minutes, the resulting error was probably less than 1 per cent. A stop watch was tried but failed to give satisfactory results as it did not always start on being released. The deflections were read at 15 second intervals, the readings being taken to the nearest $\frac{1}{16}$ inch. As no deflection was less than 1 inch and at least eight readings for each rate were taken, the resulting error is probably also well within 1 per cent. The mercury in the tubes fluctuated slightly, due to changes of pressure in the main, but these fluctuations were never more than 2 per cent of the total.

After a sufficient number of tests had been made on each length, the unit losses at the observed rates of flow were computed, 1 inch of mercury deflection being equivalent to 1.047 feet of water. These values were substituted in the Williams & Hazen formula,

$$v = c\, r^{0.63}\, s^{0.54}\, 0.001^{-0.04}$$

and the average value of c for each length obtained. From these the average value of c for each size was computed. The values of c for the same section of pipe at different rates of flow showed very little variation, the extreme varying not more than 3 per cent from the average. For different sections of the same length of pipe, however, the variation was considerable, even in the case of the lead pipe. Table 1 shows the average value of c obtained from these tests, the range in the value of c for different sections of the different lengths, and the range in the average value for the different lengths.

The diameters given are those ordinarily used in connection with lead and galvanized iron pipe, and are not the measured diameters

of the actual lengths tested. Unfortunately the actual diameters are not available. The greatest variation would be expected in the

TABLE 1

Results of tests on lead and galvanized iron pipe

SIZE	DIAMETER	RANGE OF DISCHARGE	RANGE IN VALUE OF *C* 2 ft.-4 ft. lengths	RANGE IN VALUE OF *C* 15 ft. lengths	MEAN *C*
		Lead pipe			
inches	*inches*	*gallons per minute*			
½	0.50	2–16	130–155	144–150	148
⅝	0.625	2–22	140–165	147–157	152
¾	0.75	5–50	120–148	124–143	137
1	1.00	10–80	121–140	131–138	134
1½	1.50	20–200	120–149	138–143	139
2	2.00	60–300	140–170	157–162	160
		Galvanized iron pipe			
½	0.623	2–18	78–110	92–97	94
¾	0.824	5–50	88–125	97–104	101
1	1.048	10–80	100–125	106–110	109
1½	1.611	20–200	95–115	101–105	103
2	2.067	60–270	80–125	98–103	101

galvanized pipe. Subsequently four lengths of each size of the galvanized pipe were measured by filling with water and the average diameter computed, with the result shown in table 2.

TABLE 2

Actual inside diameter of galvanized iron pipe, in inches

SIZE	PIPE A	PIPE B	PIPE C	PIPE D	AVERAGE
½	0.649	0.642	0.633	0.622	0 636
¾	0.845	0.839	0.834	0.830	0.837
1	1.062	1.064	1.050	1.053	1.057
1½	1.612	1.600	1.618	1.605	1.609
2	2.080	2.075	2.071	2.090	2.079

The ½-inch pipe shows the greatest difference. If the same difference had prevailed in the pipe upon which the loss of head tests were made and the actual diameters had been used in the computa-

tions, the effect would have been to reduce the values of *c* somewhat. In the case of the ½-inch this would have meant a reduction of 4 per cent. However, as it is usually quite difficult to measure the diameters accurately, values of *c* computed on the basis of the standard diameters would be of the greater value.

Figures 1 and 2 show the curves that were obtained for the various sizes of lead and galvanized iron pipe, respectively. They have been plotted to a logarithmic scale in order that they may appear as straight lines, and be therefore more easily comparable with one another. The points that have been indicated are the values for the different sections from 2 to 4 feet long, and indicate the variations in the different parts of the same length. For the lead pipe, curves have been added in which *c* has a value of 120 and 160; and similarly for the galvanized pipe, curves in which *c* has a value of 80 and 120.

TABLE 3

Values of c, coefficient of discharge, of corporation cocks

SIZE	TAIL PIECE, ANGLE	VELOCITY IN FEET PER SECOND	
		10	30
inches	*degrees*		
½	45	0.433	0.467
⅝	45	0.496	0.500
	90	0.367	0.388
¾	45	0.433	0.443
	90	0.380	0.408
1	45	0.445	0.445
	90	0.478	0.478
1½	45	0.577	0.590
	90	0.567	0.548
1½*	45	0.351	0.298
	90	0.300	0.322
2	45	0.459	0.467
	90	0.433	0.431
2*	45	0.306	0.326
	90	0.292	0.308

* Strainer.

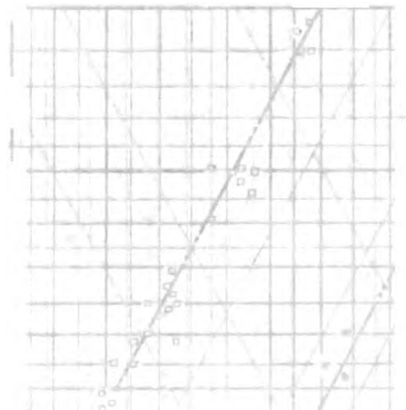


Figure 3 shows some typical sections and table 7 the principal dimensions of the various sizes and styles of corporation cocks that were tested. Cocks with strainers or eel guards are no longer used by the department. They clogged up more quickly, and were more difficult to blow out than the cocks without the guards.

TABLE 4

Lengths of lead service pipe having same resistance to flow as corporation cocks

SIZE	TAIL PIECE, ANGLE	RANGE OF DISCHARGE	CORRESPONDING RANGE OF EQUIVALENT LENGTH OF LEAD PIPE
inches	*degrees*	*gallons per minute*	*feet*
½	45	3.5– 22.5	3.86– 4.70
⅝	45	6.0– 35.0	4.96– 5.94
	90	5.0– 35.0	6.24– 7.54
¾	45	8.0– 50.0	5.67– 7.17
	90	7.0– 50.0	6.65– 7.72
1	45	14.0–100.0	7.47– 9.91
	90	16.0–100.0	7.00– 9.23
1½	45	70.0–250.0	10.00–12.38
	90	70.0–250.0	10.22–13.52
1½*	45	30.0–160.0	14.10–23.45
	90	25.0–180.0	18.20–21.45
2	45	60.0–400.0	22.60–28.50
	90	60.0–400.0	22.95–31.10
2*	45	80.0–350.0	34.00–40.00
	90	80.0–300.0	36.00–40.75

* Strainer.

Figure 4 shows the curves obtained for the corporation cocks. They have also been plotted to a logarithmic scale. The losses shown include the velocity head, entrance head, and the frictional loss in the cock. The velocity head curves for the different sizes have also been plotted.

It will be noted that with one exception, the losses through the cocks with 90 degree tail pieces are larger than those with 45 degree tail pieces, the difference being greater for the smaller sizes. The addition of a strainer or eel guard practically doubles the loss.

The relation between the loss in the corporation cock and the velocity head may be expressed by the formula $C = H/P$, in which

TABLE 5

Pressure in street mains in pounds per square inch required to give the tabulated discharge through a corporation cock and 30 feet of lead service pipe

FLOW	DIAMETER OF LEAD PIPE, WITH SERVICE COCK SIZES BELOW																			
	2 inch							1½ inch					1 inch			¾ inch		⅝ inch
	2 inch	2 inch*	1½ inch	1½ inch*	1 inch	¾ inch	⅝ inch	1½ inch	1½ inch*	1 inch	¾ inch	⅝ inch	1 inch	¾ inch	⅝ inch	¾ inch	⅝ inch	⅝ inch
gallons per minute		*		*					*									
5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	3
10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	6	10
15	..	..	..	..	..	..	..	..	..	..	..	..	3	4	5	11	12	23
20	..	..	..	..	..	..	5	..	..	..	..	5	5	6	9	18	21	38
25	..	..	..	..	..	3	7	..	..	..	4	8	8	10	14	28	32	54
30	..	..	..	..	..	5	11	..	..	2	5	12	11	14	20	39	46	
40	..	..	..	..	3	8	19	2	3	4	10	21	18	24	35	69	80	
50	..	..	..	..	4	13	30	4	5	7	15	32	28	37	54			
60	..	..	..	3	6	18	43	5	7	9	22	47	39	51	76			
70	..	..	..	4	8	25	63	7	9	13	30	68	52	69				
80	..	..	..	5	10	33	..	9	11	17	40		68					
90	..	3	3	6	13	42	..	12	14	21	52							
100	3	4	4	7	16	51	..	14	17	26								
125	5	6	7	12	25	77	..	22	27	40								
150	8	9	10	17	36	..	..	30	38	57								
175	10	12	13	23	49	..	..	41	51	77								
200	13	16	17	29	62	..	..	52	65									
225	17	20	21	37	..	..	..	65										
250	20	24	25	45														
275	24	29	30	55														
300	29	35	36	64														

* With strainer.

H is the velocity head, and P the total loss as measured by the U-tube minus the loss through the 1 foot of lead pipe. The value of C is not a constant, being in general higher for the larger values of H. The loss P also represents the pressure required to produce the velocity head H, hence C is equal to the coefficient of discharge. Table 3 gives the values of C as computed from the curves on figure 4.

The relation between the losses in the corporation cocks and the losses in pipe can be shown by computing the length of lead pipe of a size corresponding to the size of the cock, in which the loss would be the same. This equivalent length is not a constant, being greater for the higher rates of flow and for the larger cocks. Table 4 gives the range in the values of this length for the various sizes and rates of flow indicated.

The values at other rates than those indicated may be obtained by direct proportion without material error.

TABLE 6

Loss of head in pounds per square inch in 10 feet of lead pipe; velocity head not included

GALLONS PER MINUTE	⅝ inch	¾ inch	1 inch	1½ inch	2 inch
5	1				
10	2	2			
15	6	3			
20	10	5	1		
25	14	8	2		
30	....	11	3		
40	....	18	5		
50	....	....	7		
60	....	....	10	1	
70	....	....	13	2	
80	....	....	17	2	
90	....	....	....	3	
100	....	....	....	3	
125	....	....	....	5	
150	....	....	....	7	1
175	....	....	....	10	2
200	....	....	....	12	2
225	....	....	....	15	3
250	....	....	....	....	3
275	....	....	....	....	4
300	....	....	....	....	5

Tables 5 and 6 were prepared from the results of these tests and have been found to be quite useful. Table 5 gives the pressures required on the street main in pounds per square inch to discharge through the various combinations of corporation cocks and service pipes, the rates of flow indicated. The figures are also equivalent to the difference in pressure between the street main and the end of the service pipe when discharging into the house plumbing under

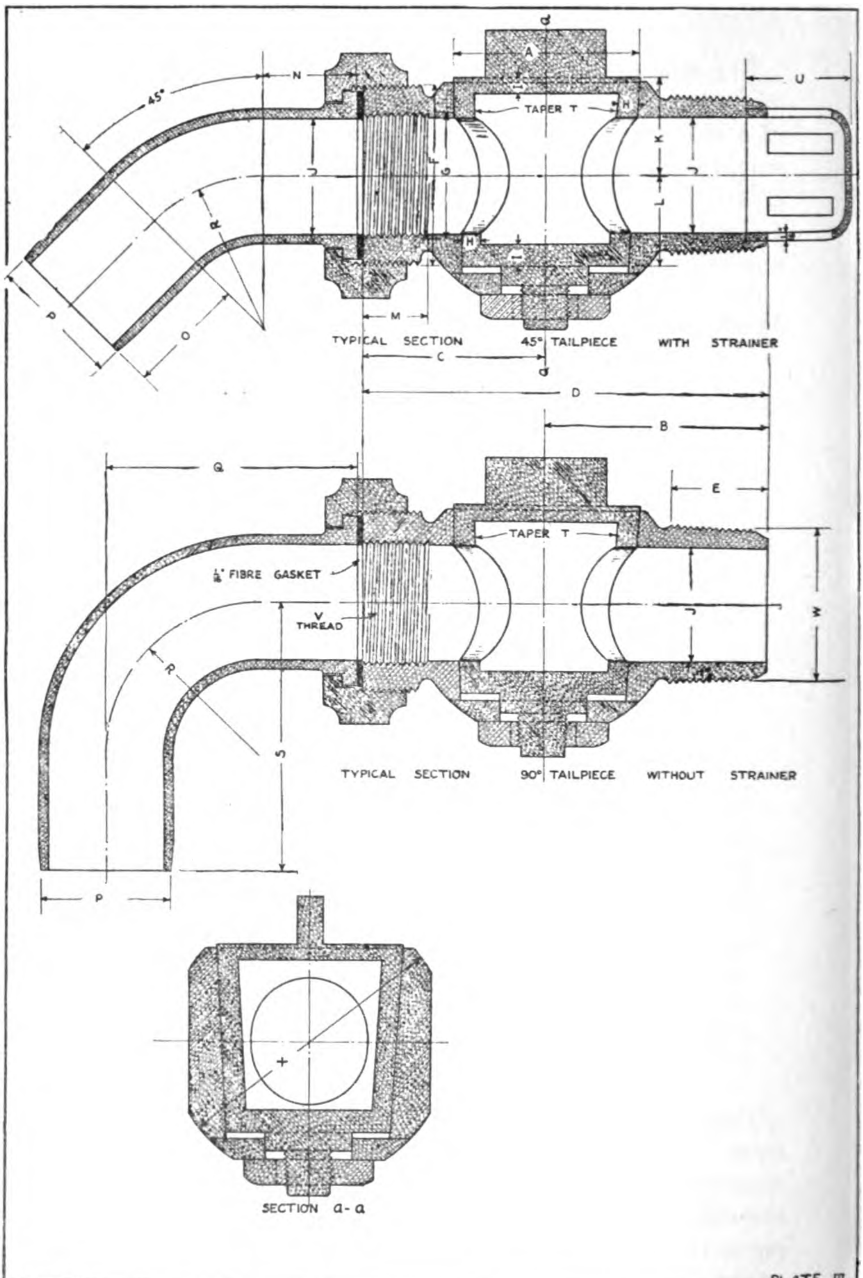
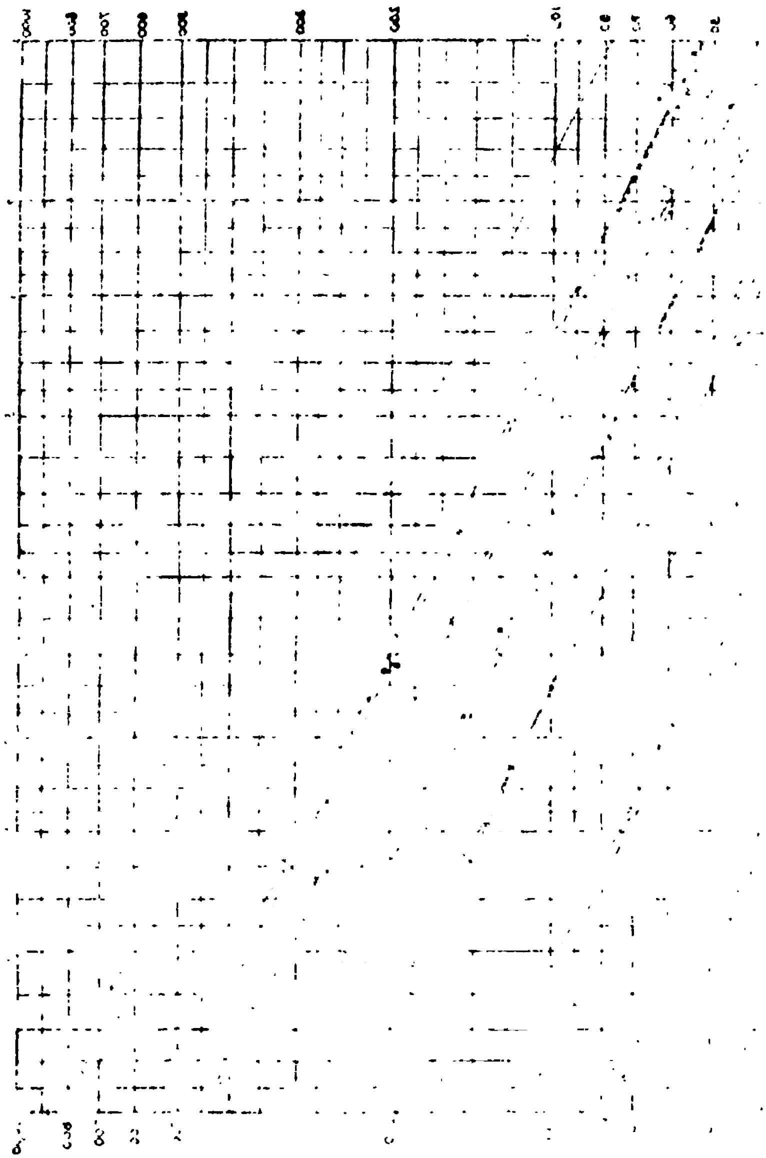


Fig. 3. Sections of Corporation Cocks Tested



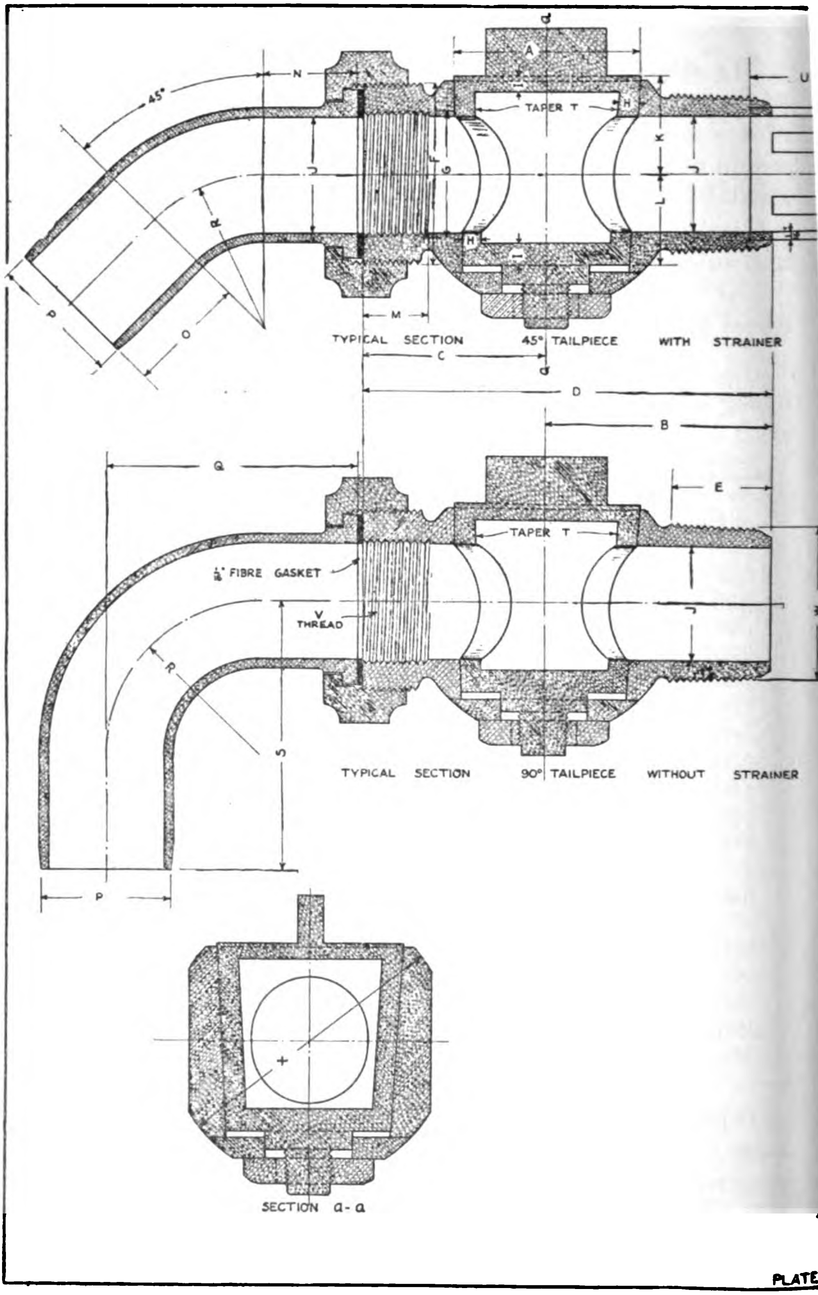
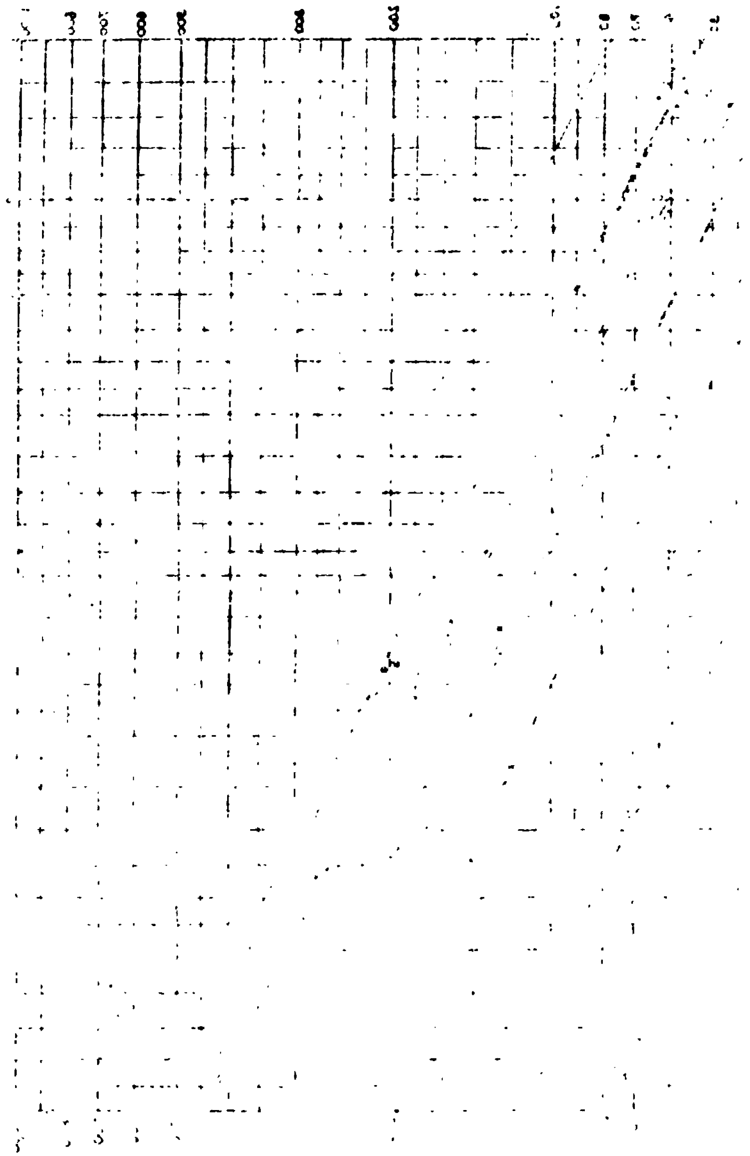
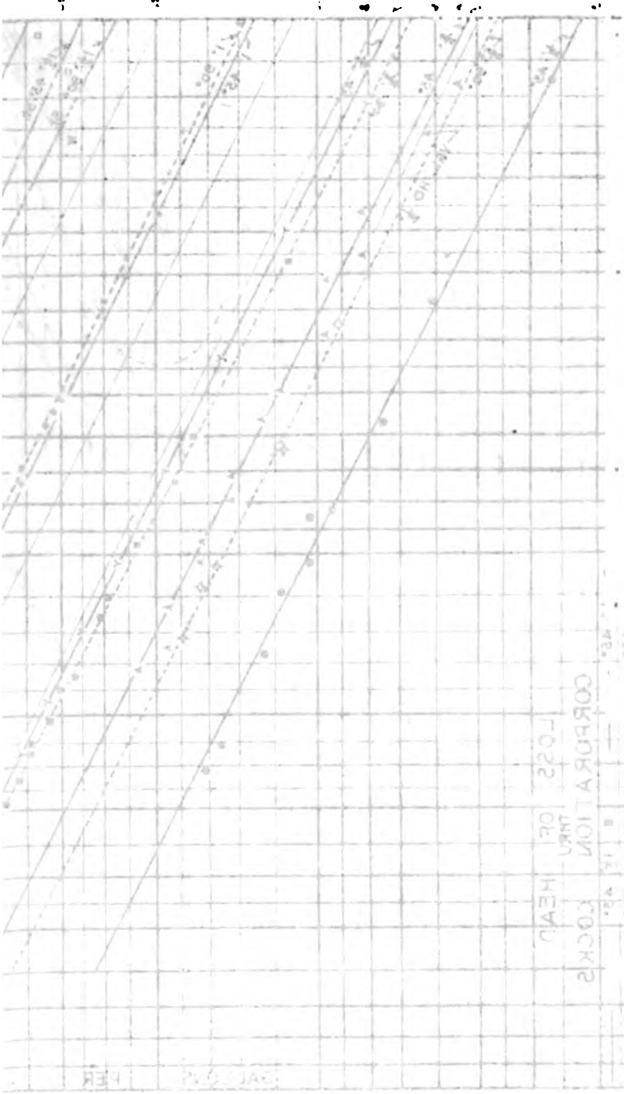


Fig. 3. Sections of Corporation Cocks Tested





pressure. The length of the service pipe has been taken as 30 feet. Table 6 gives the loss through 10 feet of lead pipe. From these two tables the pressure required for any length of lead service can be readily computed.

TABLE 7

Dimensions of various sizes of corporation cocks illustrated in figure 3

	$\frac{1}{2}$ INCH	$\frac{5}{8}$ INCH	$\frac{3}{4}$ INCH	1 INCH	$1\frac{1}{2}$ INCH	2 INCH
A	$\frac{15}{16}$	$1\frac{1}{8}$	$1\frac{21}{64}$	$1\frac{5}{8}$	$2\frac{21}{64}$	$3\frac{3}{8}$
B	$1\frac{7}{8}$	$1\frac{7}{8}$	2	$2\frac{3}{32}$	$2\frac{7}{8}$	$3\frac{13}{16}$
C	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{21}{32}$	$2\frac{7}{16}$	$3\frac{1}{4}$
D	$3\frac{3}{8}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{5}{16}$	$7\frac{1}{16}$
E	1	1	1	$\frac{15}{16}$	$1\frac{1}{4}$	$1\frac{9}{16}$
F	0.944	$1\frac{9}{32}$	$1\frac{9}{32}$	1.605	2.351	2.853
G	0.632	0.753	0.878	1.112	$1\frac{11}{16}$	$2\frac{9}{16}$
H	$\frac{3}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{5}{16}$
I	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
J	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2
K	$\frac{23}{32}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{3}{4}$
L	$\frac{17}{32}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{13}{16}$	$1\frac{3}{16}$	$1\frac{9}{16}$
M	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	$1\frac{3}{8}$
N	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$
O	$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$
P	$\frac{21}{32}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{3}{16}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Q	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$
R	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	2
S	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$
U					$1\frac{3}{16}$	$1\frac{1}{4}$
V	12	12	12	12	8	8
W	0.822	1.053	1.145	1.361	2.024	$2\frac{9}{16}$
X	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{11}{16}$	$4\frac{7}{8}$
T (TAPER)	$1\frac{1}{4}''$–$1'0''$	$1\frac{1}{4}''$–$1'0''$	$1\frac{1}{4}''$–$1'0''$	$1\frac{1}{4}''$–$1'0''$	$1''$–$1'0''$	$1''$–$1'0''$
Strainer............. Number of openings...........					6	10
Strainer............. Size of openings...............					$\frac{7}{8}''$x$\frac{5}{16}''$	$1\frac{1}{8}$x$\frac{5}{16}''$

PRESIDENT'S ADDRESS[1]

BY MAJOR THEODORE A. LEISEN

Conditions during the past year have been abnormal and as a natural sequence, the affairs of the Association to a certain extent have been affected thereby. For this reason, it is not possible to expatiate upon any extraordinary achievements or record-breaking accomplishments as a result of the year's progress. That we have held our own so well financially and in membership is ample reason for congratulation and is testimony of a healthy, stable existence.

If a brief reference may be permitted to the internal dissensions which characterized the last annual meeting, it can be stated that the storm clouds which then hovered over the Association's affairs—fraught for a time with a menace of serious disaster—appear to have cleared away, and the hope is sincerely expressed that now and in future, all personal feelings will be suppressed in the interests of that spirit of universal coöperation and service without which this Association cannot expect to attain and maintain the purposes for which it was formed, and which all members who have the interests of the Association at heart so earnestly desire.

The revision of the Constitution is one of the most important matters which is now before the Association, and some of the amendments as finally concurred in by the Committees, it is believed, will have a tendency to insure smoother operation in the affairs of the Association, and eliminate or reduce undue friction, if the amendments are adopted. The amendments involved have received very careful consideration by both the Committee on Revision of the Constitution and by the Executive Committee, and the results were placed before the membership in ample time to permit a thorough understanding of the questions at issue before the matter is brought to a vote.

At no time in the history of the country has the necessity for the beneficial influence of national associations been more vital to their membership than during the existing crisis and this is particularly

[1] Read at the St. Louis Convention, May 15, 1918.

so in connection with those representing public utilities in general and public water supplies in particular.

One of the principal lines of service which this Association should endeavor to render at this time to that large portion of its membership who represent directly or indirectly the management of water works, is coöperative assistance through proper channels in obtaining fuel and other commodities essential to the continuous and efficient operation of the plants. The first move in this direction was the affiliation with the National Committee on Gas and Electric Service, and was productive of considerable good, but there was an apparent lack of effort to take full advantage of this committee's facilities and services, or much better results might be recorded. Other steps tending to effect these results are now under contemplation and it is hoped that the combined efforts along these lines will afford marked relief in obtaining prompt deliveries of coal and other supplies to all water works administrations.

Despite certain handicaps which hampered some of the work during the past year, the activities of the Association as depicted by the official Journal have not fallen below the average standard of other years, but a still higher standard is attainable and it sh·uld be the earnest effort of every individual member to strive unremittingly for that goal.

There are many other questions to which it would be possible to refer, but the crowded condition of the program offers an excellent excuse for condensing this address, and the over-burdened status of my position at this particular time affords an even better one for not inflicting on the members a prolonged statement or discussion of matters with which they are already familiar.

In conclusion, I desire to express my sincere gratitude to the Association for the confidence shown and for the honor conferred in electing me to the Presidency, and to offer my apologies for not having given to the affairs of the Association the full measure of attention which the position of president demands. For the major portion of the year, it has been a question of service to the Association or service to the Government, and what I was able to give was devoted to the latter, to the detriment of the Association's affairs. The committees have mostly performed excellent service, and their good work was in marked contrast to the delinquency of your President.

HISTORY OF THE ARTESIAN WATER SUPPLY AT SAVANNAH, GEORGIA[1]

By E. R. Conant

Savannah, the county seat of Chatham County, Ga., has a population of 80,000. The county is in the eastern section of the coastal plane, and has an area of 370 square miles. Savannah is 18 miles from the sea coast and is on the south bank of the Savannah River, and the elevation of the city above sea level ranges from 14 to 40 feet.

Historical. Previous to 1854, when the city had a population of 15,000, the domestic supply was obtained from wells ranging in depth from 15 to 30 feet. They were of the ordinary circular type lined with stone or brick, and ordinary hand pitcher pumps were placed at the top of them. The city maintained these wells and pumps, and the records show that the annual expenditures for obtaining a ground water supply by maintaining some 150 wells, ranged from $3000 to $7000. The records state that the water furnished was soft and wholesome, but in one of the old city reports, it was stated that mulberry trees growing anywhere near these wells were required to be removed, because they affected the purity of the water, in what way the author cannot imagine.

The city also constructed and maintained approximately twenty large brick cisterns under ground, each with a capacity of from 5000 to 10,000 gallons, which were kept filled for fire service only. These were abandoned many years ago, but the author in paving a street recently discovered one of these old cisterns and after opening it at the top found it to be partially filled with clear water, and there was no algae growth on the walls. The cistern was entirely closed, the water entering it by percolation through the brick. Unfortunately no bacteriological analysis was made of the water to ascertain whether it was potable.

In 1851, the mayor and aldermen engaged the services of A. W. Craven, chief engineer of the Croton water works, New York, as consulting engineer to design a project for obtaining a surface water

[1] Read at the St. Louis Convention, May 14, 1918.

supply from the Savannah River. This supply was put in operation in 1854, and the author found in one of the old reports that the first Worthington type of pumping engine was installed at Savannah under this project. Water partially filtered was taken from the Savannah River at a point opposite the thickly populated portion of the city, and pumped to a standpipe, from which it was distributed by mains over a portion of the city. After twenty years operation of this plant, it was believed that the health conditions of the city would be improved if the intake at the river was further from the city proper, and a new pumping station, locally known as the river station, was constructed at a point 1¾ miles up the river, and this station was used for pumping direct from the river until 1887, when an artesian well supply was adopted.

Introduction of artesian wells. In 1879 the mayor of the city brought up the question of the possibility of obtaining a water supply by boring artesian wells. Little was known of artesian wells at this date and for a number of years the city authorities were skeptical of obtaining a suitable supply by this method. As far as the author can learn the earliest artesian or deep well in Georgia was bored in Savannah in 1882, and the boring of others soon followed, as they were self-flowing and furnished a most desirable quantity of water. The agitation for obtaining an artesian well supply for Savannah resulted in the boring of several wells, and at the end of 1887, 15 wells had been bored near the river pumping station alluded to above, and a small reservoir was constructed into which the water from the wells entered by gravity, and the city's supply was obtained from these self-flowing wells. With a diminution of the flow, due to the lowering of the static head, the wells failed to furnish the necessary supply, and to make up the deficiency a portion of the supply was taken from the Savannah River and temporarily mixed artesian and river water was used.

Geological data. The Atlantic coastal plane reaches from New York to the Florida straits. This plane is underlaid by a great sediment of superficial deposits consisting of gravel, sand, clay, marl and loam, and in certain localities lime rock full of cavities exists, which forms the aquifer into which the water pours from the catchment areas through a stratum of sand beds, which have a general seaward dip. These aquifers form valuable underground water resources. Along the coast of Georgia there is a strip 25 to 40 miles wide bordering the coast overlying water-bearing strata or aquifers through which water

comes from a catchment area located from 80 to 100 miles northwest of this coast line. The character of the water obtained from the aquifer along the Georgia Coast is in almost every instance potable and suitable for a domestic supply, and at this time there are over 1000 wells tapping the aquifer in this state alone. The direction of the flow from the catchment area to the aquifer at this locality is in a southeastern direction, and it is observed that the interference of one well over another is less when they are bored on an axis perpendicular to the line of flow than where they are promiscuously bored, as was the case with the first artesian well supply at the river pumping station, above referred to.

The strata penetrated in boring artesian wells at Savannah consist of 250 to 300 feet of clay with interbedded layers of marl and sands, and under this from 220 to 250 feet of porous limestone, or more strictly speaking, limestone with voids or cavities. The principal water-bearing stratum is in the limestone. Below this, for 300 to 350 feet, a formation of marl intermixed with some shell is found until a shallow stratum of flint rock is struck at about 950 feet below the surface. Below this, for a depth of 50 feet, is another water-bearing stratum of limestone similar to the upper aquifer.

Gwinnett Street pumping station. As noted above the supply at the river station was insufficient to meet the needs of the city, and in 1891 a new project was adopted for supplying it with artesian water, which project at the time was one of the most carefully planned of any in the country. The site selected for the new pumping station is two miles southeast of the river station, well within the corporate limits of the city. The city employed as consulting engineer, Thomas F. Johnson, of Chicago, who at the same time was installing an artesian supply at Memphis, Tenn. The plan here consisted of boring 12 wells 300 feet apart in a continuous line nearly perpendicular to the line of the subterranean flow. The depth of the wells is from 500 to 600 feet. They are all 12 inches inside diameter, and the casing is driven to a depth of approximately 250 feet, where it is imbedded in rock so that there can be no contamnation of the aquifer from surface water following the casing. A brick conduit 6 feet in diameter was constructed from 10 to 16 feet below the surface of the ground on a level grade, with elevation at mean low water, into which the wells flow, and the water is carried through this conduit to the pump well at the station.

The pumping equipment consisted of two Holly engines of the Gaskill type of 10,000,000 gallon capacity each. A 42-inch main was laid from the pumping station to the edge of the thickly populated section of the city, 4000 feet distance. This station is $\frac{3}{4}$ mile from the center of the water supply distribution. No standpipe or reservoir was provided, and at this date there is no standpipe or reservoir other than a small pump well which has a capacity of 40,000 gallons, and the brick conduit, which has a capacity of approximately 600,000 gallons. This pumping station was put in operation in 1893, and has been in continuous use without interruption since then.

When the Gwinnett Street station was put into operation the river station was shut down, and was not utilized, except for emergency use, for 11 years, and since then this station has only been used to make up any deficiency in supply that the Gwinnett Street station could not furnish with one pumping unit, the supply from the river station being about 10 per cent of the total consumption. The wells at the Gwinnett Street station were at first self-flowing, but the flow gradually lessened and an air lift plant was installed in 1902, consisting of two Ingersoll-Rand air compressors of 1800 cubic feet capacity of air per minute. In 1908 a single air compressor of 1200 cubic feet per minute capacity was installed at the river station. The method of operation at the Gwinnett Street station, is to work one unit for a month, then shut down this unit and operate the other, except in case of fire, when an increased supply is required, then both engines and compressors are immediately put in operation. The river station is only operated during the day, except when a peak load has to be provided for.

Static head of wells. When artesian wells were first bored in and near Savannah, the water rose to from 30 to 35 feet above mean low water. With a continuous draft upon the aquifer, the static head fell, and the rate and amount of lowering of the static head depends largely upon how concentrated the draft on the aquifer is at any locality. Take, for instance, the river station where 25 wells were bored promiscuously within a 10-acre tract. Records do not give the fall in the static head at the river station after the wells were first bored, but the diminution of the flow that occurred would indicate that within three years after they were put in operation the static head dropped at least 20 to 25 feet. Artesian wells were bored at the river station in 1887–1889, and between that year and 1893, the domestic supply, with the exception of a small percentage of pumpage

at times from the river, came from these wells. With the construction and operation of the Gwinnett Street station in 1893, the river station was shut down, excepting for very brief periods, until 1909. Since 1909 both stations have been in operation, but only from 1,000,000 to 4,000,000 gallons daily has been drawn from the wells at the river station; therefore, there has only been a light draft on the aquifer at this locality, and the elevation of the static head has changed but little.

At this time the elevation of the static head at the river station is from 4 to 6 feet above mean low water, whereas at the Gwinnett Street station, only 3900 feet away, where there is heavy continuous draft upon the wells, the static head of the 12 wells adjacent to it averages 12 to 14 feet below mean low water. Sufficient data have been collected to show approximately the rate of lowering of the static head at this station from 1893 to the present time, and if the fall in the static head was graphically shown, the line showing the lowering of the static head would form a parabolic curve with the flattening out of the curve occurring at this time.

In 1890, when the wells were first bored at the Gwinnett Street station, the static head there was approximately 28 feet above mean low water, and the static head of the original wells bored in this vicinity was approximately 35 feet above mean low water so that the operation of the wells at the river station previously to the boring of the wells at the Gwinnett Street station evidently effected to some extent the water pressure in the aquifer at the Gwinnett Street station. Three years after the wells were first put in operation at the Gwinnett Street station, the static head fell 12 feet, and five years later the static head had fallen 5 feet further. Unfortunately there is no record of the elevation of the static head in 1902, when the air compressors were first installed, and not until 1915 was the static head carefully determined by the author, when it was found to be from 10 to 12 feet below mean low water. In other words, during the last 17 years, the static head at the Gwinnett Street station has dropped approximately 22 feet, equivalent to an annual drop of somewhat less than 1½ feet.

Assuming that a still further flattening of the curve of the static head lowering occurs, it will be a long time before the drop will fall to such an extent that the cost of obtaining water either with electrically driven pumps or with an air lift system will be excessive. With the present air lift system the additional cost per million gallons

pumped per each foot of sinking of the static head is 15 cents. Undoubtedly a continuous heavy draft on the aquifer will cause a continued lowering of the static head, but if there should be an interruption in pumping for any length of time the static head would return to an elevation considerably above mean low water. Wells just bored on the prolonged axis of the existing wells and distant 900 and 1600 feet from the nearest old wells have the elevation of the static head at approximately low water. New wells that have been bored within a distance of 2 or 3 miles of the river station are self-flowing at this date.

In connection with the static head it is necessary to consider the draw-down, which is proportional to the draft placed upon the wells. The draw-down at the Gwinnett Street station wells is from 12 to 15 feet, and at the river station approximately 6 feet, but if the air is cut off, the water rises rapidly to its ordinary static head elevation.

Interference of wells. As stated above, the wells at the river station were bored promiscuously in a small area, without any relation to the line of flow of the aquifer, and the wells interfere one with the other much more than at the Gwinnett Street station. Nine months ago a new well was bored within 90 feet of the one of the old wells at the Gwinnett Street station, and there has been very little interference between the two.

The static head has apparently only dropped 2 feet at this point, due to the additional draft on the aquifer. That this well has not interfered more with the old wells near it, can only be explained by the fact that the new well is a little deeper and evidently enters pockets that the old well does not draw from. We have one deep well 1500 feet deep, within 1000 feet of one of the old wells, which taps two aquifers. The static head is higher and the draw-down in this well is very much less than in the other wells.

Capacity of wells. While the aquifer has been tapped for a period of twenty-nine years, there is just as much water in the aquifer at this time as there was originally, as shown by the capacity of the wells, but it is necessary to go a little lower for the supply. When the wells were first bored at the river station the capacity of the 22 wells was approximately 6,000,000 gallons and it is easy to obtain this quantity now. Reference to the capacity of the wells at the Gwinnett Street station for various periods gives better data as regards the strength of the aquifer. When the 12 wells at the Gwinnett Street station were

bored in 1892, the total flow from it was 10,300,000 gallons per day. In a year or two this flow diminished to 9,500,000 gallons and in 1897 the records show the flow to be further reduced to 5,500,000 gallons. In 1900 the flow was slightly less, recorded as 5,000,000 gallons, and in 1902 the flow was approximately the same, but when the air lift system was introduced in 1902, the capacity of the wells increased to 10,300,000 gallons per day. Tests made by the author of the capacity of the same wells in 1915 showed the supply to be at the daily rate of 15,000,000 gallons, and at this date the city is obtaining this quantity without any effort, in fact at this time it is pumping from 8 wells and obtaining 10,000,000 gallons per day. This shows that there is a great subterranean flow, which is believed to be inexhaustible, and all that is needed is for a suitable distribution of wells to draw water without creating a too concentrated draft on the aquifer. The air is applied to the wells through 2½-inch pipe with no nozzles or air pump at the lower end, and the submergence is around 60 per cent. Not a well has been lost since they were first bored, this being due to the wells entering a limestone formation where there are no heavy pockets of sand.

Before the installation of the air lift, attempts were made to increase the flow of the wells by dynamiting, which produced no appreciable benefit. Another method was attempted of applying water under pressure to the wells. This was done by laying an 8-inch main along the axis of the wells and connecting the well with it. This flushing did increase the flow for the time being about 12 per cent. The running pressure of air at the wells at this time ranged from 22 to 30 pounds, with 45 pounds air pressure at the station.

Chlorine contents. One feature with artesian wells that requires attention is the possibility or probability of salt water entering the aquifer as the static head is lowered. It so happens that several analyses of artesian water were made in 1893 and the chlorine content of the water at that time was found to be 6.1 parts per million. In 1915 the chlorine content was found to be 6.2 parts per million, showing that up to this date there had been no increase in the salinity of the water. The wells that go to the lower aquifer reach a water of slightly different chemical analysis, the chlorine contents being about 14 parts per million.

Analyses of water from the artesian wells at Tybee, fifteen miles distant, which is on the sea coast, show the chlorine contents to be 6½ parts per million, so that apparently there is no fear of the water

at Savannah becoming too salty for potable or domestic use for a long time to come.

Tidal interference. There is some oscillation in the static head of some of the wells, corresponding to the rise and fall of the tide at the sea coast, and this amounts in some localities to about 4 feet. It is not appreciable in the wells at the Gwinnett Street station, where water is drawn from the aquifer all the time. At the river station, when there is cessation in the pumping, the static head varies somewhat, and other wells in the county that are self-flowing have a stronger flow when the tide is high than when the tide is out.

Consumption of water. Savannah at this date has a population of approximately 80,000. The average consumption is 10,300,000 gallons per day, or a per capita consumption of 129 gallons. The consumption has fluctuated in the past from 115 to 165 gallons. This has been due in part to abnormal pumping during extraordinary cold spells and the extension of house drainage system, but especially to the large waste due to faulty plumbing.

A pitometer survey was made in Savannah in 1912 and considerable saving in pumpage was brought about by the work done following this survey. In the mains the pressure, which at one time was 30 pounds, has been increased to 50 pounds. The city has commenced the installation of meters and has passed an ordinance requiring stop and waste cocks on all risers. It is carrying out house to house inspection of all plumbing fixtures. The installation of only 700 meters last year brought about 4 per cent reduction in the per capita consumption.

Fuel consumption. Accurate records have been kept of the fuel consumption at the Gwinnett Street station since it was first put in operation in 1893. When the new pumps were first installed the consumption was 2000 pounds per million gallons pumped into the mains. Rather singularly the consumption sank regularly for a period of five years when 1450 pounds of coal pumped the same amount of water. This was during the period whem the wells were self-flowing. The lift from the pump well is approximately 12 feet and the pressure in the force main was at that time from 20 to 30 pounds. The installation of the air compressor increased the amount of fuel required to 2600 pounds of coal per million gallons pumped into the mains, but after efficiency was brought about in the operation of the air lift, the fuel required fell to 2100 pounds. From 1904 to 1914 the annual increase in consumption of coal has been 90 pounds per mil-

lion gallons pumped. This, of course, is accounted for by the slowly receding elevation of the static head, to the machinery becoming older and to the increase in pressure in the mains from 30 to 50 pounds, so that at this time the consumption is 3240 pounds of coal per million gallons.

The city's destructor plant, which destroys the city's refuse, was put into operation in March, 1914, and is operated by steam furnished by burning the refuse. The excess steam not required to operate the plant itself is conveyed from the boiler to the main boiler head at the pumping station. This excess steam for three years and nine months has resulted in the saving of $26,100 worth of coal, and if there was enough refuse to operate the destructor plant at its full capacity, the saving for this period would have been about double this amount. This total cost of operating the station, including maintenance, fuel and incidental expenses not excluding interest on investment, depreciation, or allowing for any sinking fund, has been on the average of $12. per million gallons pumped. At this time with abnormal conditions, the operating cost has risen to $16. per million gallons.

Deterioration of well casing. Investigation made of one well casing removed from the River Station showed it had suffered deterioration. On account of slight contamination of the water occurring at the river station two years ago, a thorough investigation was made to ascertain how this occurred, and this investigation has shown beyond a doubt that infiltration of surface water occurs through some of the well casings. In order to prove this, an attempt was made to withdraw one 10-inch casing and with the application of two 100-ton jacks the author succeeded in withdrawing 150 feet of the pipe, which then broke off at this depth. In the casing, at a point about 40 feet below the surface, a hole was found which it was thought at first might be due to electrolysis but was finally concluded to be due to corrosion. At present, to avoid contamination of the water, in the morning before pumping occurs into the mains, it is customary to apply the air compressor and waste the water from the wells for a period of one hour. This eliminates the accumulation of infiltered water through the previous night and with this operation there has been no trouble, as continuous pumping creates internal pressure in the casing greater than the outside pressure, thus keeping out infiltration. These casings have failed after 26 years life, and it has been planned to do away with this station within a few months.

The plan for improving the Gwinnett Street station includes the installation of electrically operated pumps of 1½ million gallons daily capacity, thoroughly overhauling the present machinery, and setting additional meters to reduce the waste, so that the one station with one unit will supply the present demands.

Cost. The construction of the river station, which was met by a bond issue, cost $220,000; other outlays, such as the cost of the air lift system, for this station have been $57,000.

The initial cost of the Gwinnett Street station was $427,000, and since its construction to the present date $80,000 was expended for air lift plant and for new wells, making total construction cost $784,000.

Financial management. With the exception of one bond issue of $200,000, to pay for the first construction in 1882, all costs of construction, maintenance, extensions and renewals have been paid from the current revenue derived from the sale of water.

The management of the water works of this city has not been unlike the management of many municipalities, in that no sinking fund has been provided and any excess revenue over the expenditures for outlays or operation has been thrown into the treasury and used for any municipal use. No charge has been made against various departments for water furnished; the city has been exceedingly liberal as regards free water and only recently has taken proper steps to prevent and avoid wastage by the consumer.

From 1882 to the end of 1917 the revenue from the water works department has been in round figures $3,359,000. The total expenditure for the operation and maintenance for this period was $1,320,500; for construction of plant and mains and installation of air lift system, boring and connecting wells, a total of $1,328,500 was expended.

The cost of construction, boring of wells and connecting them, amounted to $1,328,500. An inventory of the water works department made by the author at the end of 1917 places the value of the physical portion of this department at $826,950; therefore, the depreciation is estimated at $501,550.

The total outlay for the past 36 years was $2,649,000, giving a surplus, excluding depreciation, of $710,000, or a net surplus, allowing for depreciation, of $208,450. There are no outstanding liabilities and the plants have been fully paid for. If the plant was privately owned, interest on investment would have to be considered, but this is more than offset by the public and free service that has been given.

It can be seen that rates for water have been fixed very closely to what has been required to meet the expenditures, but there should have been a sinking fund provided. Had there been a sinking fund the much-needed rehabilitation and extension of the water works system could be carried out at this time without recourse to a bond issue, which will be required within the very near future.

The per capita income is very much less than the average per capita income of other municipalities. In Savannah it is somewhat less than $2.00 per year per capita, while the average in the United States is about $2.50 per capita.

The total pumpage for 26 years was 97,408,000,000 gallons, making the total cost per million gallons pumped, including cost of construction, maintenance, all outlays, including extension of mains, etc., $27.20.

WATER WASTE ELIMINATION. METHODS AND RESULTS AT OAK PARK, ILL.[1]

By H. P. T. Matte

All will agree, no doubt, that the most important factor in the elimination of waste is complete meterage. This belief is held firmly in Oak Park, but the author will try to show that it must be supplemented by other measures in order to be entirely effective. These have been divided into the following heads:

1. Strict maintenance of meters.
2. Rigid collection of high bills due to leakage or waste.
3. Efficient complaint department, to take care of complaints caused by excessive water bills. This includes education of consumers.
4. Master meter for measuring the entire supply to the distribution system. That is, a recording Venturi meter, or any of the various types of recording pitometers, with accompanying recording pressure gauges.
5. Periodical waste surveys.

To these may be added the following, important, although often overlooked, elements in the control of waste:

6. Absolute control of all the divisions of the water department by the manager.
7. Strict adherence to the rules and regulations, or ordinances. This means that the water department must be upheld by the municipal authorities. In other words, let the water works be out of politics entirely.

The foregoing rules have been in force in Oak Park, and to that fact the author ascribes the following results:

During the four-year period between 1913 and 1917 inclusive, although the population has increased 34.6 per cent and the number of services or meters 32.5 per cent; the daily consumption increased only 20.7 per cent. The daily per capita consumption has decreased from 75 gallons to 67.6 gallons, or 10.6 per cent, the minimum night

[1] Read before the Illinois Section at Urbana, April 18, 1918.

rate of consumption diminished 37.5 per cent and the ratio of the minimum night rate to the average daily consumption, dropped from 40.8 to 21.2 or 48 per cent. The percentage of water accounted for by meters has increased from 72 per cent to 83 per cent.

Oak Park has always been 100 per cent metered. All the water pumped into the distribution system, except that which is lost through underground leakage, is delivered through meters. This

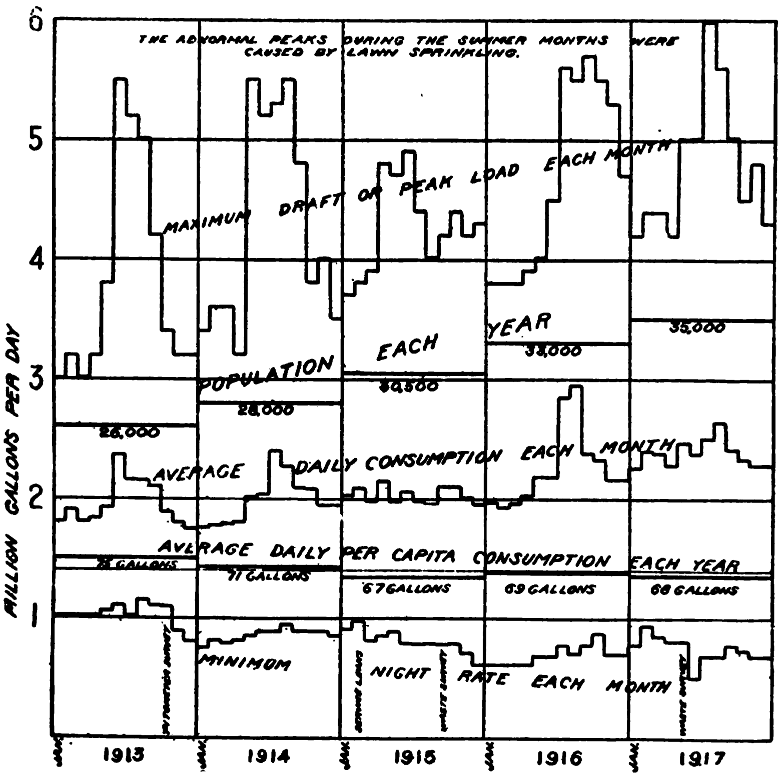


FIG. 1. WATER CONSUMPTION AT OAK PARK, ILL.

includes all municipal buildings, watering troughs, drinking fountains, street sprinkling water used in parks, and fire hydrants when used for other than fire purposes. Water used in the construction of houses is sold through meters buried in the parkway. Moreover there is no free water.

Referring to item 1, maintenance of meters, all meters are tested periodically, a practice which has been found profitable, although

not required by the Public Utilities Commission. Meters are read every quarter in a continuous reading system, for which purpose the city is divided into six districts so that those found to be not registering can be brought into the shop, repaired and put back into service within a week after being read.

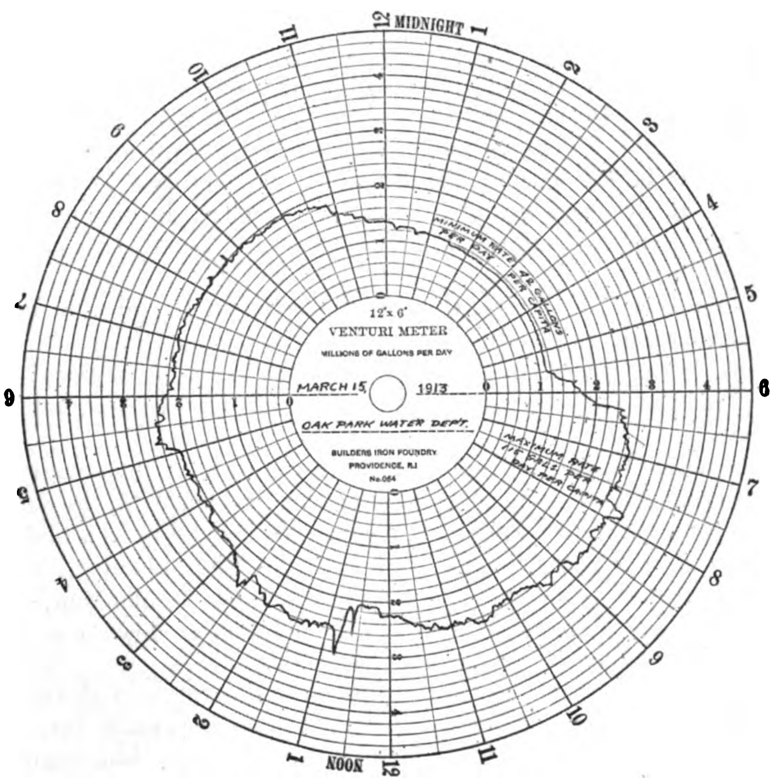


FIG. 2.

The second point, the rigid collection of high bills due to leakage, is important and has a beneficial effect on the success of the meter system. In other words, although it may be hard on the consumer, he will, if properly impressed, appreciate the importance of watching his fixtures and become educated in spite of himself.

No reduction in bills is made on account of leakage. Short and pointed instructions, which include the policy of the Water Department, are printed on the backs of the water bills. If the complain-

ant has been guilty of the characteristic failing of mankind, that of being unobserving and neglecting to read the information supplied to him every three months, he deserves to pay for his inattention.

This does not mean that the department is heartless and does not admit mistakes. The consumer is given the benefit of the doubt from the first, owing to the fact that the department realizes that it is but human and can be in error in several ways. In fact the department lets it be known that it is glad to correct its faults. If, however, upon thorough investigation it is found that the water was consumed through leakage or otherwise wasted, the bill must be paid. In order to be fair certain allowances are made if the waste was in the ground and invisible. In this case the lowest rate at which water is sold in Oak Park is allowed, although the quantity consumed may not justify the consumption to be placed in that class.

In any case of high bills, whether this concession is given or not, if the consumer is plainly unable to pay the bill as it stands (these claims being investigated), an installment plan of payment is adopted; but with the provision that the bill must be paid within a year.

The reason for this attitude is this; every student of human nature knows that if a water department is reputed to be lenient, the average person takes a chance and depends upon his ability as a bluffer to get out of paying the bill. Talk is cheaper than plumbing bills. If he is victorious because "he has been unfortunate and won't let it happen again," he surely will. In the old days of leniency it was found that the average consumer *did* do it again.

But it is impossible to handle this matter properly without an efficient complaint department, for it is then impossible for the department to prove its case. Every water works man who has had to deal with consumers under the meter system is aware of the number of excuses and prevarications that are evolved in order to make the management believe that there was a mistake made in the reading, that there are no leaks, that the fixtures have been repaired recently, that the meter works when no water passes through it, that the meter reader is in collusion with the "bunch of grafters in the office" and reads the meter from the next block, and so on.

Oak Park, however is prepared to prove to all these amateur lawyers that they have no case in court. There is a record of all complaints of whatever nature that have been made to the water

department and about the water department for the past five years. These are arranged by years in 3 by 5-inch card files, and are the original records. All calls are recorded on the same size cards, three colors being used to distinguish between complaints relating to meters and bills, complaints and job orders relating to the mechanical division, and those relating to delinquent bills. This record is very valuable in refuting unjust accusations, in tracing past records, and for the purpose of settling especially difficult problem.

All complaints concerning high bills are investigated and a comprehensive written report is made to the consumer. The nature of the complaint is written on the card provided for that purpose and is given to an inspector who makes a specialty of investigating high bills. It has been found impracticable for the meter reader to waste time making investigations. He notes all unusual sounds or evident leakage on the reading slip and a special call is made. Sometimes a consumer is dissatisfied even after a second investigation, and he is allowed to hold the payment of the bill until the next quarterly statement, when he will see for himself the result of stopping small leaks. If, however, a rebate is yet expected or sought, a final notice of "Shut off for non-payment" is issued and the water is shut off in spite of threats of litigation.

For the purpose of determining the cause of persistent high bills, where "there are only two in the family, no leaks, and there is no sprinkling done; while the family next door has three or four children, does its own washing, sprinkles the lawn all day, and has only minimum bills," the department has evolved a recording detector which is substituted for the meter and which gives a graphic record of the consumption for twenty-four hours or a week. It is thus possible to spot the number of times the faucets are opened, the number of baths with the quantity used each time, and the number of times the toilets are used. It has thus been possible on many occasions to show that the toilet valve would not work about every fifth time it was operated, and that the lady of the house was apparently too clean, having the habit of letting the water run in the kitchen sink too long each day or that somebody took a cold bath every morning and consumed about 50 gallons each day in the operation, or that a thermostat used by a central heating plant leaked at some time during the day, or that the toilet was used too often to wash down foreign substances that did not belong there, or finally that the servant was very wasteful.

The complaints on account of high bills dropped in number from 2000 in 1913, to 600 in 1917, due to the education of the consumers who, realizing that the department means business, is strictly impartial and is able to help them reduce their water bills, have begun to coöperate with the department.

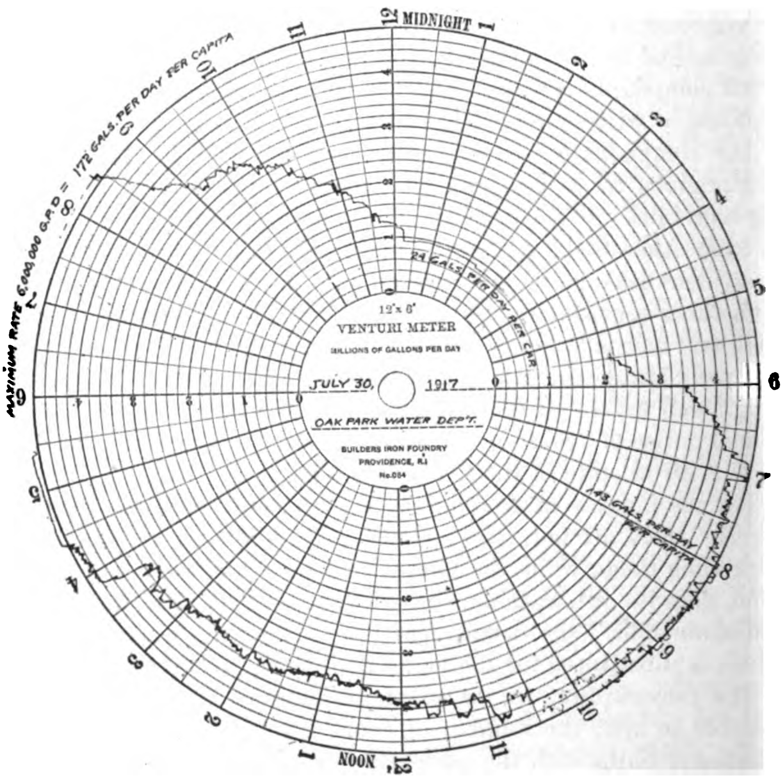


FIG. 3.

The third item in the efficient elimination of waste is the installation of recording pressure gauges and a master meter directly on the distribution system. The combination of the two devices is a great aid in estimating the rate of consumption during the night, which is due to leakage alone, in noting the progress each day in the stoppage of leaks, and in determining the necessity for making a special waste survey. The efficiency of the pumping station attendants as well as that of the pumps can be determined at a glance.

Many plants are equipped with Venturi meters or pitometer recorders placed on the main leading to filter beds, or to reservoirs or standpipes. The character of the consumption cannot be accurately determined by meters so placed that the fluctuations cannot be seen.

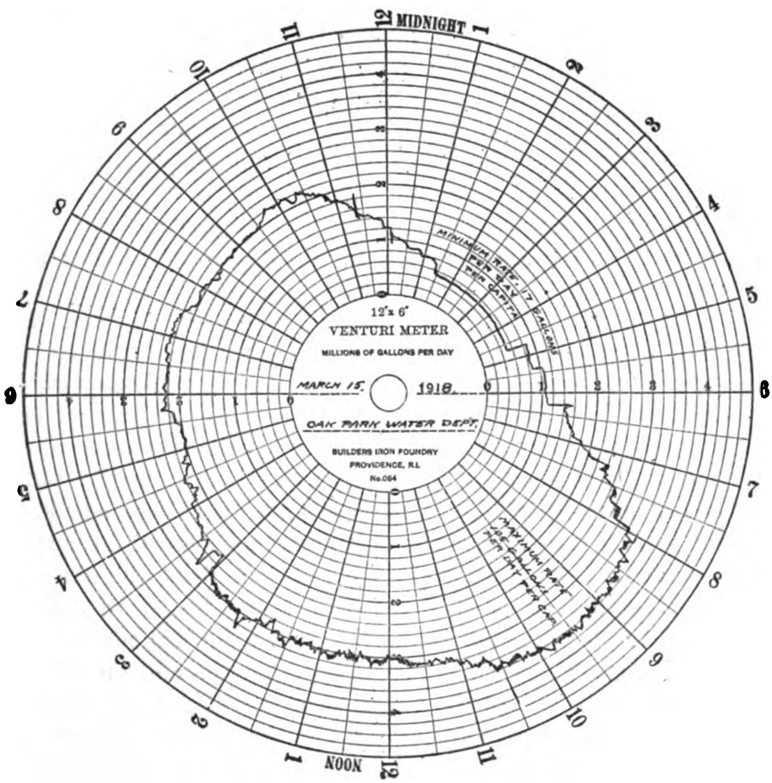


FIG. 4.

The waste survey, one of the most important elements in the prevention of continued needless waste on a metered water system, is next on the list, and the author hopes to see it become more popular.

In order to shorten the work of making waste surveys and avoid unnecessary work, it is advisable to make first a rough survey of the entire city with a pitometer, which is done by isolating certain districts and measuring all the water consumed through one of the

mains as a feeder. Here is where the master meter on the distribution system comes into use. The Oak Park department often shuts down large districts for a few minutes and notes the drop on the Venturi chart. It is impossible to do this at night because the quantity is only 400 gallons per minute between the hours of 1 and 4 a.m. In fact the smallest pump is so throttled in order to maintain the assumed pressure of 40 pounds that the opening left is equal in area to that of a 2-inch pipe. The Venturi meter is not sensitive enough at that low velocity; but it is possible to accomplish nearly the same result in the day time during periods of steady consumption when there is a draft of 2000 or 3000 gallons per minute. In this case the drop has been found sufficient to allow the making of an analysis of the leakage conditions. The pitometer is the surest way, however, for it is possible with it to obtain accurate information and so eliminate the "good districts."

After the pitometer survey, especially when the leakage is so small that there is little velocity in the mains, the "hydrant and hose method" follows logically. It is practically useless to expect any headway if a displacement meter is used, as the rate of consumption and the minimum flow cannot be accurately determined. The Oak Park department uses a 2-inch Venturi meter, but a pitometer inserted into a short piece of pipe 2 inches or smaller in size is as good. A manometer and as much condemned fire hose as can be obtained from the fire department, completes the outfit.

During the summer of 1917 the department tested 18 miles of mains, and stopped leakage amounting to 220,000 gallons per day. This represents a saving in the cost of water purchased from the city of Chicago, of $5,000 and the outfit used cost only $150, exclusive of the hose. It also accomplished the reduction of the night rate of consumption to the assumed standard of 20 per cent of the average daily consumption.

It has been the Oak Park experience that in order to be most efficient, a water department must be under one head. That is, not only should the manager take care of the mechanical end of the water works system but also the financial part. He should also inaugurate the policies. It is very difficult to handle complaints regarding high bills and to give satisfaction if the money is collected in one department, "shut-offs" for non-payment of bills are handled in another, and the bills are rendered in either of the foregoing or yet in a third one.

It is trying for the superintendent or manager to make a decision and be obliged to back down if the complainant is able to obtain a concession from someone higher up, who is not vitally interested in the efficient operation of the department and yields to pressure from some political adherent. It is difficult to enforce ordinances or rules if exception must be made in the case persons of influence or important political henchmen. It is impossible to prevent needless waste of water if certain organizations or institutions, by vote of the municipal authorities, are allowed free water against the advice of the manager.

The author acknowledges that absolutely nothing could be done toward the efficient management of the Oak Park water department were it not that the municipal authorities are intelligent business men who investigate all complaints thoroughly before acting upon them, and stand back of all the department's apparently arbitrary decisions, which, though they may cause temporary bad feeling, make for the betterment of the department. In short the department is able to live up to the water ordinance to the letter. It is not a mere scrap of paper.

A PRELIMINARY ANALYSIS OF THE DEGREE AND NATURE OF BACTERIAL REMOVAL IN FILTRATION PLANTS[1]

By Abel Wolman

The determination of a law of bacterial removal by rapid sand water filtration plants is of great practical importance and utility. Such determinations of plant efficiencies are valuable as indicators not only of present but also of future performance. The objection is, however, often justly raised against the attempt to predict quantitatively the possibilities of bacterial removal, that existing numerical measures of performances are misleading and in some cases even harmful. The calculation of percentage removal from raw water to effluent is an illustration of the type of measure which has arithmetical accuracy, but little logical basis. It is quite evident, however, that it would be desirable to measure quantitatively the performance of a plant in such a way as to obtain a comparative conception of how well or how badly it is being operated.

Since at present no agreement exists among operators, designers, or public health officials as to a standard of "good performance," because, in the past, agreement has been prevented by the interminable search for a "standard effluent," itself the subject of disagreement, it becomes necessary to attack the problem of rating or standardizing plant accomplishment from another angle. In this discussion, an initial search is made for certain basic characteristics of rapid sand filtration. The term, rapid sand filtration, is here used more broadly than usually, to describe the entire process from preliminary coagulation through sedimentation or settling, filtration, and disinfection.

The measure of variable phenomena by comparison with ideal or "normal" conditions is a procedure common to scientific analysis. The application of this method offers here a fruitful means of testing our ideas of filtration efficiency. The first problem obviously consists in the attempt to determine a possible correlation between the

[1] Read before the St. Louis Convention, May 15, 1918.

number of bacteria in the final effluent of a filtration plant and the number in the raw water. A numerical statement of the problem should be clearer. If a plant uses a raw water containing 500 bacteria per cubic centimeter and produces an effluent containing 10 per cubic centimeter, will the same plant produce an effluent of 20 per cubic centimeter when the raw water content is 1000 per cubic centimeter? Can one predict, in other words, with any degree of precision, what effluent counts should be normally attainable with varying raw water counts?

The use of a "percentage efficiency" is of but little value in the solution of this problem, since that measure is predicated upon the very assumption that the effluent counts vary directly, rather than more complexly, with raw water counts. The fallacy in this view need hardly be demonstrated at this late period in the development of filtration practice.

The norm or ideal performance from which it is possible to obtain hypotheses as to standard empirical accomplishment is not difficult to deduce. The "normal empirical performance" may be defined as the accomplishment of a filtration plant which is known to be operating successfully. Successful operation can be said to exist wherever there is an unquestioned superior bacteriological and physical quality of effluent, consistent performance, excellent control, and scientific observation of operating details. Plants whose performance may be used as the basis for comparison and for the derivation of the law of bacterial removal, are not at all rare. In this analysis, the operating statistics of the filtration plant at Avalon, Maryland, owned by the Baltimore County Water & Electric Company and operated by S. T. Powell, were used.

This plant obtains its raw water from the Patapsco River, a highly polluted stream, ranging in turbidity during the year from 0 to 5000 parts per million and in bacterial content (20°C. gelatine-48 hours), from several hundred to 150,000 per cubic centimeter. The watershed of the stream is composed largely of cultivated areas, with no large sewage polluting influences. This water is treated with aluminum sulphate, at an average rate of 0.8 grain per gallon, and is then allowed to settle for four hours. After leaving the sedimentation basin it is treated with calcium hypochlorite with an average dose of 0.34 part per million, and then passes through the rapid sand filters which have a capacity of 2,500,000 gallons per day.

The plant is controlled scientifically by a trained operator with the aid of modern equipment and laboratory observation. During several years of operation the bacterial content of the effluent has not exceeded, at any time, 20 bacteria per cubic centimeter. Presumptive tests for B. coli in lactose broth have indicated positive tests in 1 cc. less than 2 per cent of the time during any year. The

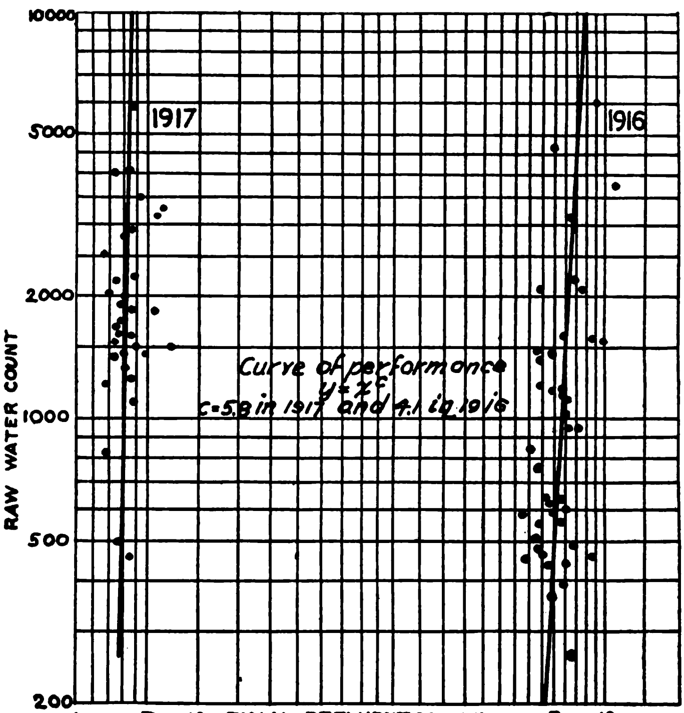


FIG. 1. BACTERIAL REMOVAL BY THE AVALON RAPID SAND FILTRATION PLANT DURING 1916 AND 1917; 20°C. BACTERIAL COUNTS USED

number and kinds of bacteria are determined in raw water and final effluent every day and general experimental data are constantly collected.

It is clear, therefore, that the plant in Baltimore County approaches so closely, from the standpoint of operating results, the ideal plant as to justify the use of its performance as the basis of a law of filtration.

In order to determine with some degree of accuracy the form of a characteristic empirical performance curve, the results of raw water and final effluent counts of the Avalon plant were plotted on figure 1.

In order to avoid plotting a mass of points which would tend to confuse the reader, seven-day averages of both stations, rather than daily results extending over a period of nineteen months in 1915, 1916, and 1917, were used. In plotting these values, approximately 520 daily analyses were summarized. These were obtained in consecutive months and under every phase of operating conditions. No counts were discarded as being unfair or incorrect. Figure 1 represents, therefore, the normal daily performance of the plant for more than a year and a half.

A study of the samples plotted on figure 1 reveals at once a consistency of arrangement. It is clear, too, that the performance of this normal plant is represented by the curves shown on figure 1. Inasmuch as these curves are practically straight lines, within the limits shown, the derivation of their equation is simple. The equation of a straight line, when the results have been plotted on a logarithmic basis, is given by: $c = \log y \div \log x$, where c is a constant for this particular plant, and y and x are respectively the raw water and final effluent counts.

It would appear, therefore, that the "normal empirical performance" is represented by a curve having the equation: $y = x^c$. A tentative hypothesis, with regard to bacterial removal by filtration action, may be promulgated, therefore, as follows: The final effluent count, under normal operating conditions, is an exponential function of the raw water count. This hypothesis provides a means of determining whether or not a plant under scrutiny is, at least, "performing normally," where normal performance would be interpreted as conformity to the logarithmic curve of filtration. Figure 2 illustrates, for instance, the failure of plant A to perform its function efficiently. By comparing the points on figure 2 showing the operating statistics of plant A with the points and the form of resultant curves in figure 1, it becomes clear that the plant A is erratic in performance in so far as the graphic representation of its operation departs from what we have reason to believe is a characteristic form of ideal curve of bacterial removal.

The "normal performance" curve demonstrates the fallacy of assuming that the *difficulty* of removal of bacteria is relatively the same regardless of the number of bacteria in the raw water. Although this assumption is rarely publicly proclaimed, it is usually summoned, however, to the aid of those plants which, for one reason or another, are so unsuccessful as to require a specious hypothesis,

fairly reasonable to the layman, to support their claims to maximum efficiency of 99 per cent plus. The practical results of a scientifically controlled plant certainly seem to lead to the conclusion that increases in raw water bacterial content decrease the corresponding bacterial content *interval* in the final effluent.

It should be added, too, that the equation of normal performance, $y = x^c$, offers a new quantitative measure of the efficiency of any plant, obtained by evaluating in any case the constant, c. Such a

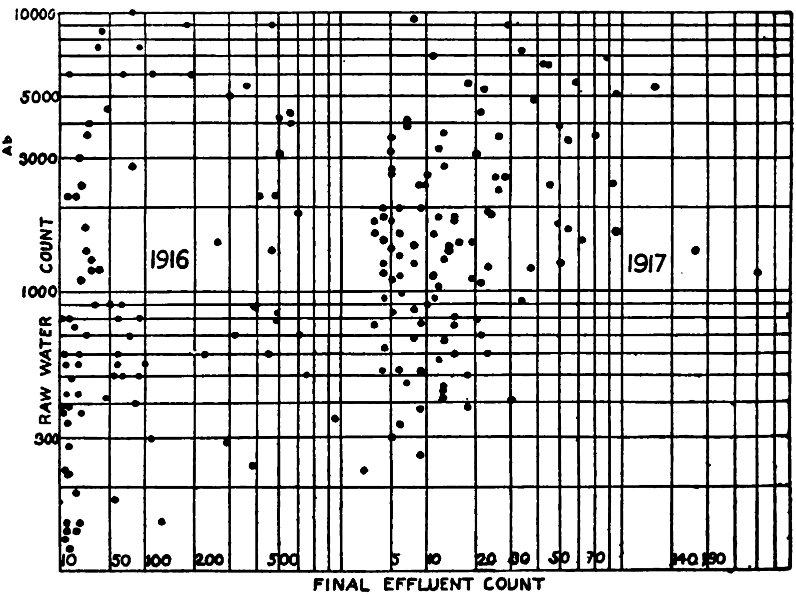


Fig. 2. Inconsistency of Performance of Plant A as Indicated by 20°C. Counts

measure, among other qualities, has the advantage of a rational basis and of a practical significance. Its use has been discussed elsewhere[2] by the author.

What absolute value this constant, c, or the so-called "coefficient of efficiency," should attain is dependent upon individual opinion of "good performance." It is of interest to note, however, that, in a survey of 19 rapid sand filtration plants, varying in size from 2.2 to 80.0 million gallons filtered per day, the coefficient of efficiency of these plants has attained an annual average of over 2.5. The raw

[2] *Jour. Amer. Pub. Health Assoc.*, November, 1916.

waters which these plants had to treat contained turbidities ranging from an annual average of 1 to 561 parts per million, and average bacterial contents from 350 to 16,500 per cubic centimeter. The 19 plants chosen, therefore, for the evaluation of c, are representative, in their initial conditions, of rapid sand filtration.

The probable existence of the law of filtration, $y = x^c$, combined with known values of c, practically attainable, gives the investigator

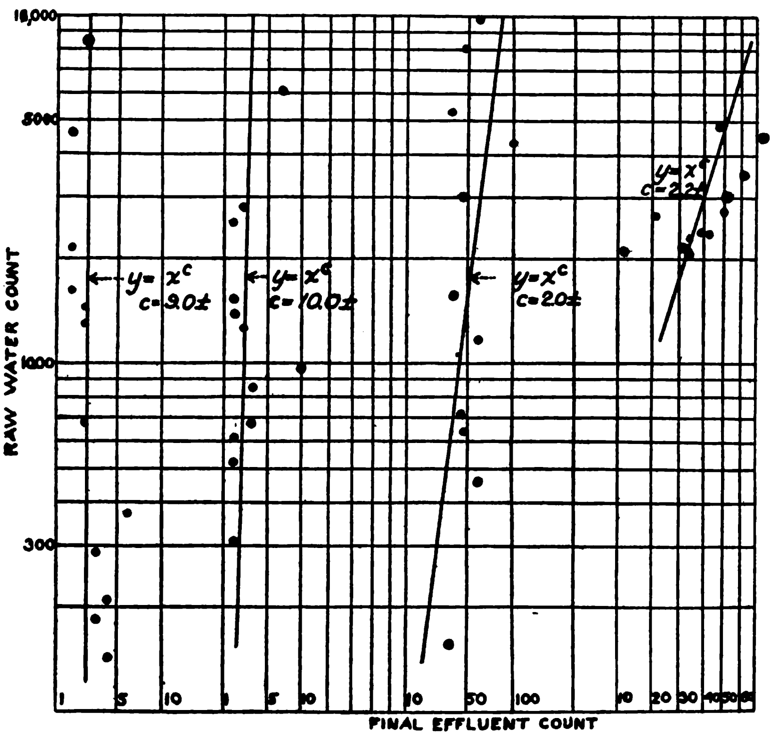


FIG. 3. PERFORMANCE CURVES OF FOUR LARGE RAPID SAND FILTRATIGN PLANTS

of filtration plant accomplishment the fundamental criteria with which to measure both the character and the amount of removal in any particular plant. The objection may be raised to the above method of critical standardization of plants, that all do not function in a similar manner, on account of differences in raw water, resulting from peculiarities of suspended matter, variations in resistance of

bacteria, and other similar factors. This objection does not seem to the author to be entirely valid, since peculiar characteristics of raw water are usually provided for by variations in design, such as increased periods of sedimentation and greater doses of disinfectant. It is reasonable to suppose, therefore, that given plants, initially properly designed for local conditions, should function according to some common law, since death rates under disinfection, devitalization and sedimentation and filtration of bacteria differ in the degree, but not in the kind, of changes effected.

The preliminary theory of bacterial removal by filtration is supported by the curves shown in figure 3, where are plotted the average monthly results from several large rapid sand plants in the United States. The monthly, instead of the weekly, results are used since the latter were not obtainable. The form of curve would be the same in both instances, while the value of the constant may change. It is quite obvious that each plant follows in its performance the characteristic $y = x^c$ curve.

Since the death-rate of bacteria under the action of disinfectants, and under well defined conditions, has been shown,[3] to follow in general the law: $c = \frac{1}{t_2 = t_1} \log \frac{y}{x}$, it will be necessary to look for the causative factors of the $y = x^c$ law in other phases of the system of rapid sand filtration. It is the author's purpose to study further the bacterial removal in the individual and distinct processes of coagulation, sedimentation, and filtration proper, with a view to throwing further light on the problem of causation.[4]

[3] H. Chick, *Jour. of Hygiene*, Vol. 8, 1908; Vol. 10, 1910.

[4] Strictly speaking, the equation of a straight line curve plotted on logarithmic axes is: $y = bx^c$, where b is the intercept on the y axis. In that case, c becomes $\frac{\log y - \log b}{\log x}$ rather than $\frac{\log y.}{\log x}$ Log b is infinitely small in our particular problem, since b, the intercept on the y axis, would be equivalent to those raw water counts which produce resultant final effluent counts of one. Since zero counts are rarely obtained in filtration plants, even with extremely low raw water counts, it is conceivable that the performance curve in the "normal operation" described above would intercept the y axis at some point approaching unity. Log b, therefore, would approach zero and could be neglected in the evaluation of c. It is evident, therefore, that $c = \frac{\log y}{\log x}$ measures in each case, with sufficient accuracy, the slope or inclination of the performance curve, the significant index to the efficiency of bacterial removal.

SOME ASPECTS OF CHEMICAL TREATMENT AT ST. LOUIS WATER WORKS[1]

By A. V. Graf

The principal streams contributing to the water supply of the city of St. Louis are the Mississippi, Illinois and Missouri Rivers. The Illinois River enters the Mississippi 33 miles north of the intakes at the Chain of Rocks and in traversing this distance a more or less intimate mixture of the two waters is effected. The Missouri River enters the Mississippi 5½ miles north of the intakes and causes a pressing of the Mississippi River water upon the east bank of the river and in this way, as a rule, very little mixing of the two waters occurs by the time the water reaches the intakes. At times the turbidity of the water on the west side of the river is ten times as great as that of the water on the east side, and at other times the color of the east water is 25 parts per million greater than that of the west water, showing the incompleteness of the mixing of the two waters. With a high stage in either river and a low stage in the other, the mixing of the waters is more complete.

The waters in each of these rivers have certain characteristics which become of greater or less interest as the stages of the rivers vary. The Mississippi River drainage area being covered with swamps, the water in this river becomes highly colored at times of heavy run-off, while the Illinois River, carrying a large amount of sewage, contains colloidal organic matter which seems to act as a protective colloid on the turbidity carried by this river. The water in the Missouri River, always turbid, becomes much more so at times of heavy run-off. The dissolved solids in these waters vary considerably but dissolved solids offer no difficulty in the treatment of the water and are therefore of less interest.

The river water enters the plant through two intakes, one, the old or west intake, 1500 feet east of the west bank of the river and connected to the wet well by a 7-foot circular, brick-lined tunnel, 2197 feet long. The other, or east intake, is 700 feet east and 200

[1] Read before the St. Louis Convention May 15, 1918.

feet north of the west intake and is connected to the wet well by an 8-foot circular, concrete-lined, tunnel 2747 feet long.

The water drawn through the west intake is principally Missouri River water for the greater part of the year, while the water drawn through the east intake is that of the mixture of the Mississippi and Illinois River waters, although at times the water at both intakes is practically the same both chemically and physically.

The east intake was in service only ninety-seven days during the past year whereas the west intake was used for three hundred and fifty days. Because of the greater difficulty of treating the water from the east intake, this is not used unless low stages of the river or anchor ice, or both, are affecting the pumping.

The water entering the tunnels flows by gravity to the wet well, whence it is pumped, against a dynamic head of 58.3 feet, into the delivery well and flows from there to the grit chamber where the average velocity of flow, at a rate of pumping of 150,000,000 gallons per day, is only 0.33 foot per second. In this chamber the coarser and heavier part of the suspended matter is deposited, the amount removed depending upon the character of the suspended matter as well as upon the amount present in the water. The efficiency of the grit chamber is shown in the fineness of the material removed, over 50 per cent of the matter deposited passing a 100-mesh sieve. The tons of matter removed by the grit chamber during the past year was 63,703 or 23 per cent of the total suspended matter present in the water.

Leaving the grit chamber, the water flows through a short conduit to the mixing chamber, where milk of lime and a solution of sulphate of iron are added. These chemicals are prepared in the coagulant house for addition to the water and are pumped a distance of 900 feet to the mixing chamber.

The lime is weighed out in automatic scales and is dumped into circular slaking tanks which are provided with revolving rakes. The temperature of the milk of lime in the slaking tank is kept at 200°F. This is accomplished by keeping up the temperature of the fresh water supply by passing it through the coils of a heater tank into which the milk of lime at 200° is drawn. From 4 to 4½ pounds of water per pound of lime are used in slaking. The water overflowing from the water tank is run into a cooling and diluting box, where the temperature is reduced to as low as 64° in winter time to 108° in summer. The strength of the milk of lime as pumped is 38,600 parts per million of CaO.

A slaker tank is kept in service until the accumulated unslakeable material is great enough to impede the motion of the rakes. From 50 to 150 tons of lime are slaked before a tank is taken out of service, the amount depending upon the purity of the lime. Tests made to determine the effect of limes of varying percentages of CaO upon the amount of lime that could be slaked before a slaking tank had to be taken out of service, showed that for every increase of 1 per cent in the available CaO, above the lowest lime tested, an additional 10 tons could be slaked. Contracts for lime are let under a specification requiring a lime of 85 per cent CaO, with a bonus or penalty of 1.5 per cent for each 1 per cent above or below the required 85 per cent.

The sulphate of iron is measured by passing it through an adjustable orifice onto the surface of a cylindrical drum, revolving at a constant speed and is discharged in a continuous flow into a tank, where it is dissolved without stirring, by water entering through a manifold at the bottom of the tank, the solution being drawn off through an overflow.

The mixing conduit into which the chemicals are delivered is a reinforced concrete box, 2382 feet long, 32 feet 1 inch wide and 12 feet 6 inches high, divided longitudinally into four compartments, each 7 feet wide and 11 feet high. The four compartments are supplied with stop-plank openings so that they may be thrown in parallel, used in series or withdrawn from service for cleaning. In normal operation the water enters the west channel and travels the full length four times, a total of 9528 feet, having an average velocity of 3.3 feet per second when the rate of pumping is 150,000,000 gallons a day.

Provision is made so that the lime or iron may be added to either of the four compartments, but the lime is added, for the greater part of the time, to the raw water as it enters the mixing conduit and the sulphate of iron as it leaves the conduit. The period of mixing averages about one hour. The sides and bottoms of the first two compartments are badly coated; the coating on the sides is practically all calcium and magnesium carbonates and magnesium hydroxide while the bottom coating consists of the sand and unslakeable material present in the lime added, bound together by the precipitated calcium carbonate and magnesium hydroxide.

The value of the mixing chamber is shown by an occurrence of last year. A leak in the south end of the mixing conduit, due to the failure of the contractor to properly plug a drain, caused the conduit

to be taken out of service. The water was passed from the delivery well direct to the first of the sedimentation basins, the sulphate of iron being added in the tunnel at the coagulant house and the milk of lime at the delivery well.

The turbidity of the water in the delivery well was 2500 at the time and the turbidity of the water in the last of the sedimentation basins was 20, the amounts of chemicals added being 6.25 grains of lime per gallon and 0.25 grain of sulphate of iron. After the mixing conduit was taken out of service, the sulphate of iron was increased to 2.50 grains per gallon, the lime remaining the same. In forty hours the turbidity of the water, in the last of the sedimentation basins, increased to 40, the turbidity of the river water remaining practically the same as on the preceding days. By adding ten times the amount of sulphate, the results were still inferior to what was accomplished with the mixing conduit in use. The additional cost due to the use of a larger amount of sulphate of iron while the conduit was out of service, one and one-half days, was $390.

The points of application of the milk of lime and sulphate of iron depend upon the condition of the raw water. With a water high in color and low in turbidity the iron is added before the lime with good results. If the high color is accompanied by a turbidity of 200 to 300 parts per million, better results are obtained by adding the sulphate of iron as the water leaves the mixing conduit. With high turbidity the lime is always added at the first opening and the sulphate of iron at the last. With low color and low turbidity due to colloidal matter, the sulphate of iron is added at the third opening, which allows a mixing through one-half of the conduit. At times with finely divided suspended matter in the raw water, the only sedimentation that takes place is accomplished in the first basin, the turbidity of the water in the last of the sedimentation basins being as great as that of the water leaving the first basin.

With high stages in the Mississippi and Illinois Rivers and a low stage in the Missouri, the worst condition is encountered. The high color of the Mississippi together with the colloidal matter in the Illinois make a water hard to handle. The use of sulphate of iron, as a coagulant, at these times is accompanied by some difficulty. The coloring matter of the water combines with the iron and instead of a diminution in color, the color is increased. The suspended matter being really colloidal and some of the iron hydroxide remaining in the colloidal condition, the turbidity of the water after sedimentation is

greater than that of the river. This highly colored and turbid water is much less amenable to treatment with sulphate of alumina. The amount of sulphate of alumina required to give the required flocculation of the suspended matter is from 4 to 5 grains per gallon. With this large amount of sulphate, the water passing the filters is clear but is still of high color, the iron content being eight to ten times as great as normally. At times when this condition occurs, no relief is experienced until the Missouri River run-off increases and thereby gives a turbid water which offers enough suspended matter for the rapid subsidence of the floc of ferric hydroxide. The more turbid the water at the intakes, the less trouble there is with turbidity causing material remaining in suspension.

After passing through the mixing conduit, the water enters the first of six sedimentation basins, each 400 feet long by 670 feet wide, of 30,000,000 gallons capacity. The first three division walls have five stop-plank openings and the last two four openings, all 4½ feet deep by 8 feet long. These openings render the sedimentation basins less efficient than would wiers extending the full width of the basins, but because of the necessity of maintaining an elevation of the water but little lower then the top of the basins, the need of stop-plank openings at times of cleaning is apparent. The time of sedimentation, based upon the capacity of the basins, varies from thirty to forty-three hours, but the actual time is much less, the effects of a change in the amounts of chemicals added being noticeable in twelve to fifteen hours in the last of the basins. About 90 per cent of the suspended matter and bacteria are removed in the first basin and 9 per cent in the remaining basins.

The total amount of matter removed from the water during the past year, including the chemicals added and the dissolved solids removed, amounted to 326,775 tons or 484,111 cubic yards. Some of the mud was removed by opening the sewer gate for one-half hour at varying intervals but the greater part was removed from the basins by labor and teams. The teams are used to draw scrapers which cut off portions of the mass of mud and drag them to the central gutter, through which water is flowing. The men are provided with scrapers which are used as such and also as braces to keep small A-shaped boxes in place, as the mud drawn by the horses and the water used to aid in removing the mud are drawn by the boxes. The cost of the removal of the mud from the sedimentation basins, not including the cost of the water, was 0.762 cent per cubic yard for the past year.

The water leaving the sedimentation basins enters a collecting conduit and passes through two 8-foot Venturi meters and into a small secondary coagulation basin, connected to secondary sedimentation basins by stop-plank openings. The solution of sulphate of alumina is added at the throat of the meters and is automatically controlled so that the quantity added per unit is constant for any setting, regardless of fluctuations in the flow through the meters.

No mixing chamber is provided here because of the low permissible loss of head, namely, 1½ feet. There are two secondary sedimentation basins, one east of the filter plant and one north, each of which is connected to the influent flume of the filters. The time of reaction and sedimentation, based on capacity, is twelve hours with both basins in service and six hours with one. The water entering the secondary coagulation basins being usually of a turbidity less than 20, little sedimentation takes place. It is not expected that these basins will need cleaning for some years.

The water entering the filter plant is passed through 40 filters, each with a filtering area of 1400 square feet, of 4,000,000 gallons capacity. The filtering media consist of 30 inches of sand above 12 inches of graded gravel. The effective size of the filter sand as placed in the filters was 0.341 mm., with a uniformity coefficient of 1.81. The effective size has increased to 0.407 mm. and the uniformity coefficient has been reduced to 1.45 due to the coating of the sand grains by material having the following composition:

	per cent
$CaCO_3$	76.00
$Al_2(OH)_6$ and $Fe(OH)_3$	15.00
$Mg(OH)_2$	9.00

Liquid chlorine, in the form of chlorine water, is added after filtration in a chamber in which the filtered water from the three connections to the effluent flume is combined. Two conduits, one a 7-foot ½-inch steel tube, the other a brick and masonry conduit 9 feet high and 11 feet wide, are connected to this chamber. These conduits convey the water to the pumping stations at Bissell's Point and Baden. The bacterial reductions caused by the chlorine were far from satisfactory until a baffle was built in the chamber to aid in mixing the chlorine with the water.

The reduction in bacteria in the water flowing through the steel line is always less than in the water in the brick conduit. Charges

of chlorine great enough to give tests for free chlorine in the water in the brick conduit, three hours after treatment, give no test in the steel line three minutes after. The disappearance and ineffectiveness of the chlorine in the water entering the steel line is attributed to the steel of the line. The Electro Bleaching Gas Company supplies the liquid chlorine which is measured and controlled by the liquid type meter apparatus also supplied by this company.

The accompanying operation record for the year ending February 28, 1918, shows very clearly the kind of water treated, the improvement in the condition of the water for each step of the purification system, the amounts of chemicals used and other details of operation.

Cost of operations per million gallons, St. Louis

	1918	1917
Old purification plant:		
Lime	$2.79	$1.89
Iron	0.55	0.61
Operating and miscellaneous expenses	1.18	1.04
	$4.52	$3.54
New purification plant:		
Aluminum sulphate	$1.16	$0.79
Chlorine	0.27	0.14
Operating and miscellaneous expenses	1.32	1.12
	$2.75	$2.05
Total cost for purification	$7.27	$5.59

Pumping

	1918	1917
Chain of rocks	$3.20	$2.437
Baden	8.984	7.134
Bissell's Point	6.825	5.308

OPERATION RECORD FOR YEAR ENDING FEBRUARY 28, 1918

Chain of Rocks filters

		Basins out of service	Days out of service	Remarks
Water pumped (Chain of Rocks) in million gallons	39,289.23			
Water consumed in million gallons	38,024.64	No. 1	24	Basins cleaned:
Water filtered	39,351.70	No. 2	24	No. 1 May, July, November, mud 128 inches
Water used in filter house operation	805.22	No. 5	11	No. 2, May, July, mud 87 inches.
Water used in coagulant house operation	97.95	No. 6	14	No. 6, November, mud 45 inches
Water used in basin operation (filtered)	278.49	No. 8	123	No. 9, August, mud 46 inches.
Water used in basin operation (unfiltered)	593.04	No. 9	9	
Water used in purification. Total	1,774.70			

Chemicals used

Description	Pounds	Grains per gallon: Maximum	Minimum	Average
Lime	30,147,933	8.00	4.00	5.371
Sulphate of iron	4,294,689	2.50	0.00	0.765
Sulphate of alumina (meters)	3,781,163	3.68	0.11	0.673
Sulphate of alumina (influent)	29,560	0.25	0.00	0.005
Sulphate of alumina (filters)	108,756	14 pounds per wash	0 pounds per wash	0.019 grains per gallon
Chlorine	74,516	4 pounds per million gallons	0 pounds per million gallons	1.89 pounds per million gallons

Variations in water

Description	River water Max.	River water Min.	River water Av.	Settled water Max.	Settled water Min.	Settled water Av.	Applied water Max.	Applied water Min.	Applied water Av.	Water to hs. pumps Max.	Water to hs. pumps Min.	Water to hs. pumps Av.
Stage of river	105	74.9	78.4									
Temperature	84	32	54									
Turbidity, parts per million	5,000	8	1,240	110	9	24	32	4	10	0	0	0
Color, parts per million	48	10	22	35	6	14	32	5	12	28	4	9
Suspended solids, parts per million	6,930	6	1,700							0	0	0
Dissolved solids, parts per million	468	190	310							370	150	215
Total solids, parts per million	7,210	400	2,010							370	150	215
Alkalinity total, parts per million	233	93	145	146	32	60	136	27	56	127	26	53
Alkalinity caustic, parts per million				8								
Alkalinity bicarbonate, parts per million	233	93	145	122		20	120	0	28	115	8	29
Hardness total, parts per million	304	116	193							188	66	108
Bacteria gelatine, per cubic centimeter	625,000	600	55,500	7,000	59	1.020	4.800	53	710	530	2	98
Bacteria agar, per cubic centimeter	27,000	110	7,300	450	15	97	290	9	57	57	2	11
Coli, per cubic centimeter	80	0.2	17.2			0.259			0.271			0.0106

Number filters in service 40
Number filtering hours 343,743
Average rate filtration, million grains daily 85.39
Rate of wash, gallons per million 21,000
Number of washes 8.931
Per cent wash water used 1.56
Average gallons used per wash 78.990

Run of filter in hours:
Max. 206.75; Min. 6.92; Av. 50.2
Run of filter in million gallons:
Max. 22.63; min. 0.876; Av. 5..67
B. coli per cubic centimeter in effluent 0.0485
B. coli per cubic centimeter tap water average 0.0121
Bacteria agar. Tap water average.. 10

Bacteria agar effluent 16
Bacteria gelatine effluent 185

THE DOUBLE 48-INCH MANIFOLD AT BISSELL'S POINT, ST. LOUIS

By C. M. Daily

A brief history of the St. Louis water works will be given, to enable the reader to understand the changing and growing conditions leading up to the present state of affairs which requires flexibility in the pumping from no. 2 engine house at Bissell's Point. To obtain the desired flexibility a chamber containing a double 48-inch manifold is now under construction about 129 feet west of no. 2 pumping station.

In the history of the St. Louis water works, the four years between 1867 and 1871 formed a constructive period, during which time was built the new pumping station at Bissell's Point, consisting of an intake tower, settling basins, low-service pumping station, clear well and no. 1 high service station. During this same period the standpipe on Grand Avenue and Compton Hill Reservoir were constructed.

In 1884 a second standpipe at Blair Avenue and Bissell's Avenue and the second high-service station at Bissell's Point were built. Another construction period was from 1887 to 1895; during this time an intake tower, tunnel, low-service pumping station and six settling basins were constructed at the Chain of Rocks and a 9- to 11-foot brick conduit connecting the settling basins at the Chain of Rocks with the settling basins at Bissell's Point, having a total length of 7 miles, were built. A third high-service station was constructed at Baden, 3.4 miles north of Bissell's Point, in 1898, and in 1905 a storage reservoir at Baden and a 7-foot steel flow line connecting with the settling basins at the Chain of Rocks were built.

After the low-service station at the Chain of Rocks was in use the intake tower and the old low-service station at Bissell's Point were abandoned, the settling basins becoming storage reservoirs. The three high-service stations received their supply of water from the Chain of Rocks by gravity flow through a 11-foot brick conduit and a 7-foot steel pipe to Baden and through a 9-foot brick conduit from Baden to Bissell's Point. The loss of head was about 1 foot in 10,000.

The high-service stations at Bissell's Point carried 85 pounds pressure per square inch and supplied the lower sections of the city, Compton Hill storage reservoir floating on the line. Baden high-service station carries 125 pound pressure per square inch and supplies the higher portions of the city. A standpipe at Compton Hill, erected in 1899, is connected to the Baden line.

From time to time additional equipments were added to the three high-service stations until 1911, when it became necessary to increase the capacity of both the Baden and Bissell's Point service. At this time the stations were equipped as follows: At Baden there were six triple expansion crank-and-fly-wheel engines four of which are rated at 15,000,000 gallons per day, and two at 10,000,000 gallons per day, the continuous working capacity being about 50,000,000 gallons. At Bissell's Point station no. 1 there were three triple expansion crank-and-fly-wheel engines having a continuous working capacity not exceeding 38,000,000 gallons per day. At station no. 2 there were three walking-beam engines built between 1884 and 1887, each having a nominal capacity of 16,000,000 gallons per day, the continuous working capacity not exceeding 30,000,000 gallons.

The problem presenting itself in the Water Department at that time was to increase the output of both Baden and Bissell's Point service to meet the increasing demands. To increase the capacity of Baden station it would have been necessary to build an additional engine house and a long 36-inch service main to reach the center of the distributing area. At Bissell's Point station no. 2 the fact that the engines had a very low efficiency (about 65,000,000 foot pounds per 1000 pounds of steam) justified their replacement. The distance to the center of the high pressure distribution area being closer, requiring a shorter and therefore cheaper 36-inch main, the loss of head in the conduit being much less than in the 36-inch pipe made it more economical to pump from Bissell's Point, except in the northern and north-western part of the city, than from Baden. It was, therefore, proper from an economical standpoint to increase Bissell's Point station no. 2 rather than Baden station. The final decision was to change Bissell's Point station no. 2 to work on both the Baden service and the Bissell's Point service.

To carry out this plan the three old engines were removed and two 20,000,000 gallon Holly triple-expansion crank-and-fly-wheel engines were installed in 1913 and one 20,000,000 gallon centrifugal pump was installed in 1915. The three pumps were designed to work either on

Baden or Bissell's Point service. The three 36-inch discharge pipes from this station were used for the new engines; one of these 36-inch mains was connected to the Baden service near Grand Avenue tower and the other two mains remained on Bissell's Point service.

The plan to install two more 20,000,000 gallon engines in this station would require extending the present by-pass arrangement far beyond its present limits in order to maintain the desired flexibility of pumping. This would require more space than there is available for the purpose. After various schemes were proposed and studied, it was decided to make the necessary by-pass connections through a double 48-inch cast iron manifold, to be built in a reinforced concrete chamber located 129 feet west of no. 2 station.

The manifold is designed to accommodate five engines, as a maximum, pumping into either Baden or Bissell's Point service with any engine. It is composed of two parallel 48-inch flanged cast iron pipes 94 feet long, spaced 12 feet apart in a vertical plane and erected at right angles to the 36-inch mains from the pumping station. The Baden service mains connect to the upper manifold and the Bissell's Point service mains to the lower.

Each main from the station will be connected to both upper and lower manifold in a vertical plane by means of a Y-branch introduced into the main about 20 feet east of the manifold. Each branch of each main will have a hydraulic-operated gate valve inside the concrete chamber. These valves will be operated from the station, permitting the engineer to pump, at will, into the 85-pound or 125-pound service mains.

Three hand-operated and two hydraulic 36-inch valves are placed on the service mains leaving the manifold and four hand-operated 48-inch valves placed in the manifold are for the purpose of withdrawing part of the system for any necessary repairs or inspection. The manifold is designed for connecting five service mains; four mains are now in place. The present plan is to use the two central mains for Bissell's Point service and the north main for Baden service: the south main, being the new 36-inch steel line, for both Bissell's Point and Baden service, the by-pass valves for this purpose being located at a distant point.

The manifolds are supported on steel I beams, incased in concrete for protection, which rest on the side walls of the chamber. The chamber, whose top will be flush with the ground at the center, is 102 feet long, 20 feet, 4 inches wide and 18 feet, 8 inches deep, all inside

dimensions. The bottom is designed to distribute the weight of the chamber and manifold over the entire area, the side walls to act as a vertical beam designed to withstand water pressure on the outside or one-half that pressure on the inside; horizontal beams at the top of the wall transfer the reaction of the wall to struts or ties across top. The struts or tie beams act also as roof girders, on which rest removable reinforced roof beams which support the removable roof slab. The roof slabs are 5 feet, 8 inches by 5 feet, 2½ inches and 4 inches. thick and are provided with openings for eyebolt connections for use in handling. The bottom of the chamber is lower than the sewers in its locality, and the drainage is effected by laying a 12-inch cast iron pipe to the sump in the engine house, where the water may be collected and pumped into the sewer.

Actual work on the chamber was started March 25, 1918. The present plan is to make the excavation and build about 44 feet of the south end of the chamber without removing the mains within this area. The reason for this procedure is that the ground-water level varies with the stage of the Mississippi River, and should the river rise above 20 feet on the St. Louis gauge it would be impracticable, if not impossible, to unwater the completed excavation without incurring heavy expense. Another reason is a possibility of not being able to get all of the castings for the manifold before the demand on the pumping reaches a high point. As a matter of safety it was thought best not to cripple this pumping station by removing any part of the old mains until it was certain there would be no delay in immediately rebuilding the new permanent mains. The second step involves the removal of the old mains in the next section of 24 feet and building the chamber and manifold complete for this distance. The third step will involve the removal of the two north mains and the construction of the remainder of the chamber and manifold. Temporary connection may be made from no. 6 pump to the completed portion of the manifold, before the last step in the construction is started, should the demand on the station at the time warrant it being done.

As simple as the construction appears from the description given, the work is viewed by the Engineering Department as a difficult operation, due chiefly to the soft treacherous ground which must support the adjacent 36-inch cast iron mains under working pressure while the excavation is being made and the reinforced concrete manifold chamber is under construction.

The excavation is being made with a clam shell. The material is dumped into flat cars and transported by electric cars to points on the Water Works property where a fill is required, and unloaded by hand. The excavation is lined solidly with 2-inch lumber and braced across the pit. The mains encountered in the excavation are supported by columns changed from time to time in order to keep their footings well below the bottom of the excavation. The ground water is removed by a 4-inch pulsometer. So far very little trouble has been experienced in the construction, The work is being done by employees of the Water Department under the author's direction, Mr. John Allgeyer acting as superintendent of the work.

The estimated cost of the work is $74,000, divided among the various items entering into its construction as follows:

Cast iron pipe, fittings, valves, etc.	$49,620.00
12 inch cast iron drains	812.00
Excavation, shoring, pumping, bracing and back-fill 2000 cubic feet at $2.00	4,000.00
Concrete, 615 cubic yards at $12.75	7,841.00
Removing mains, relaying and connecting manifold	5,000.00
Miscellaneous work, 10 per cent	6,727.00
	$74,000.00

THE NEW 110-MILLION GALLON PUMP AT THE CHAIN OF ROCKS, ST. LOUIS

By L. A. Day

In order to meet an increased demand for pumping capacity at the low-service pumping station of the city of St. Louis, a contract was awarded for a new turbine-driven centrifugal pump having a maximum capacity of 110,000,000 gallons per twenty-four hours. This will bring the total capacity of this station up to 290,000,000 gallons per twenty-four hours, which will be adequate for some time to come. The new pump will be located in the center pit, there being three pits in all. There are at present two 30,000,000 gallon turbine-driven pumps in this pit. Room was made for the 60-inch suction valve on this pump by channeling off 3 feet of the ledge on the east side of the pit for its entire length north and south. This also provides enough room in the pit for the location of the necessary auxiliaries used in connection with the new pump. The ledge was cut from solid limestone. It was also necessary to tunnel a 60-inch suction line through the limestone for a distance of 40 feet to the suction well which is common to all engines in this station. In addition to the 60-inch suction valve which is located within the pit, stop logs are provided in the wet well for making repairs on the suction valve if needed. The operating floor of the pump pit is 12 feet above the bottom. An automatic push-button electric elevator is used to reach the turbine operating floor from the ground level of the pumping station, which is 45 feet above. The pump will be required to operate under varying heads as the river rises or falls. The average total discharge head will be 60 feet with a minimum of 45 feet and a maximum of 65 feet.

The discharge pipe will be 60 inch diameter and will drop below the floor and then rise vertically, paralleling the west pit wall. The pipe will be enlarged to 72 inches from a flanged Y, which is 60 inches by 72 inches by 42 inches, due to the north 30,000,000 centrifugal pump discharging its water through the same pipe. The new unit will be provided with a 60-inch hydraulically operated discharge valve close to the Y and the old unit with a 42-inch hydraulically operated valve

close up to the 45 degree leg of the Y. The 72-inch line will be extended to the delivery well, which is a common discharge well for all pumps in this station. A 72-inch cast iron Venturi meter tube with a 36-inch throat diameter, the largest cast iron Venturi tube ever built, will be installed just outside of the pumping station.

The pump will deliver from 80,000,000 to 110,000,000 gallons in twenty-four hours against any head varying from 45 to 65 feet. This range of flexibility could not be met entirely with governor adjustment, but will be obtained by opening or closing hand operated valves on the turbine; the speed of the unit thus obtained will be further controlled by an automatic governor. This governor will be of the oil relay type, designed to permit of adjustment while the unit is in operation to any point within the required range of speed, and after being adjusted will maintain the required speed within 2 per cent variation above or below.

The maximum brake horse power of the turbine will be 1550 and the maximum water horse power required, including all pipe friction, will be 1250; the speed of the turbine under these conditions will be 3717 r.p.m. When the pump is delivering 80,000,000 gallons of water in twenty-four hours under a total head of 45 feet the turbine will run at 2946 r.p.m. The pump speed will be lowered by means of reduction gears to 352 r.p.m. when delivering 110,000,000 gallons under 65-feet head, and to 279 r.p.m. when delivering 80,000,000 gallons under a 45-foot head. The guaranteed pump efficiency will be slightly above 80 per cent under all of the specified head and capacity conditions. The suction and discharge openings to the pump will be 48 inches and the 60-inch suction and discharge piping will be gradually reduced near the pumps to this diameter.

The turbine is of the multistage impulse type and will operate with 125 pounds gage pressure and 75° superheat. Provision will be made for bleeding 1500 pounds of steam from one of the low-pressure stages for heating feed water. Bleeding this amount of steam will increase the B.t.u. duty of the unit approximately 3 per cent. The bleeder outlet will be provided with an automatic valve set to carry a pressure of 5 pounds gage on the exhaust line at all times. The dry vacuum pump is of the horizontal crank-and-flywheel type designed to operate at a speed not to exceed 115 r.p.m. The condensate pump will be turbine-driven, connected to a centrifugal pump by means of reduction gears. The circulating pump will be direct connected to the main unit shaft, and will take its water from the 60-inch suction; after passing

through the condenser the water will be discharged back into the main suction pipe. The condenser will be of the water-tube type placed directly under the turbine. Water for circulating purposes only will pass through the condenser, as an excessive amount of friction would have been obtained by passing all of the water pumped by the unit through the condenser, this being the usual water works practice. In order to derive as much heat as possible out of the exhaust steam going to the condenser a primary heater will be placed in the condenser and all the condensate from the condenser will be pumped through this heater before going to the hot well or open feed-water heater. The total condenser surface will be 2825 square feet of seamless drawn brass tubes No. 18 B.W.G., 1 inch in diameter and 12 feet long.

The unit was bought on the bidder's guarantees of duty per million B. t.u. consumed by the unit, including auxiliaries and bled steam, with the provision that the total amount of exhaust steam from the auxiliaries, plus the steam bled from the unit, should not exceed 2200 pounds per hour.

The successful bidder's guarantees were as follows:

	100,000,000 GALLON			80,000,000 GALLON			110,000,000 GALLON		
Head in feet	45	60	65	45	60	65	45	60	65
50° circulating water	113.5	120	122	107	113.75	115	114	120.75	121.5
80° circulating water	106.5	113	115	101.5	108.50	109.5	107	113.50	114.0

The average duty for all of these conditions is 114,562,000 foot-pounds per million B.t.u.'s. which is equivalent to a duty of 134,000,000 foot-pounds per 1000 pounds of steam.

Attention is called to the fact that different duties are obtained with different temperatures of circulating water. This is due to the fact that if the turbine is designed properly, better economies will be obtained with low circulating-water temperatures, owing to an increased vacuum. The average circulating water temperatures for this station throughout the year are 50° for the winter and 80° for the summer. In order to compare bids on this unit the following information was embodied in the specifications:

One million foot pounds of duty will be valued at $2000. That is, if bidder A guarantees 5,000,000 foot pounds higher duty than bidder B, $10,000 will be added to B's bid for comparison with A's bid.

Bidders were instructed to submit curves showing duties guaranteed when pumping 80,000,000, 100,000,000 and 110,000,000 gallons with circulating water temperatures of 50° and 80° and heads of 45, 60 and 65 feet.

During four-fifths of the time each year the pump operates, it is estimated that it will be called on to deliver from 80,000,000 to 110,000,000 gallons under heads varying between 60 and 65 feet. During the remaining one-fifth of the year, it is assumed this pump will deliver from 80,000,000 to 110,000,000 gallons under a 45 foot head. It was further assumed that the unit will deliver 100,000,000 gallons for one half of each year under all head conditions and the remaining half it will deliver either 80,000,000 or 110,000,000 gallons in equal parts.

The process may be represented diagrammatically as follows:

100,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots\ldots\ldots$$

Ditto for 60 ft. head x 2 = ...

Ditto for 65 ft. head x 2 = ...

$$5\,)\,\frac{\text{Sum}}{\text{Duty A}}$$

80,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots\ldots\ldots$$

Ditto for 60 ft. head x 2 = ...

Ditto for 65 ft. head x 2 = ...

$$5\,)\,\frac{\text{Sum}}{\text{Duty B}}$$

110,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots\ldots\ldots$$

Ditto for 60 ft. head x 2 = ...

Ditto for 65 ft. head x 2 = ...

$$5\,)\,\frac{\text{Sum}}{\text{Duty C}}$$

$$\text{Resultant Duty} = \frac{2 \text{ x Duty A} + \text{Duty B} + \text{Duty C}}{4}$$

All of the above conditions must be verified by complete shop tests before the unit is shipped. These shop tests must be on the turbine, gears and pump assembled complete. The shop tests must show duties at least those guaranteed by the contractor and checked by the city's representatives.

After the unit is installed it will be subjected to an endurance test of ten days of twenty-four hours each. A station duty test will then be made as a check on the shop duty test, the station test to be conducted entirely in accordance with recommendations laid down in the latest A.S.M.E code for testing steam driven pumping machinery. The capacity will be measured with a Venturi meter.

The physical data of the unit and auxiliaries is as follows:

Turbine

Make....................DeLaval
Brake horse power of turbine.......... Normal 1300, maximum 1550
Number of stages....................13
Number and diameter of rotors..................4—27½ in.; 9—24 in.
Revolutions per minute under maximum conditions............. 3720
Method of speed control..........Jahn's governor through oil relay
Percentage of speed obtainable above and below normal by governor regulations..............................6 above and 15 below
Percentage of speed obtainable above and below normal by hand-regulated nozzle............Approximately 6 above and 20 below
Net weight of turbine without bedplate, pounds.............. 24,000
Diameter and length of bearings, inches..................... 4½ x 14
Diameter of shaft in rotor, inches........................... 10
Diameter of steam admission, inches.......................... 6
Diameter of steam exhaust, inches........................... 36

Reduction gear

Net weight of reduction gear complete without bedplate, pound, 32,000
Diameter of driven gear, inches.............................. 63.4
Diameter of pinion, inches.................................. 6
Width of face of gear in pinion, inches...................... 29¼
Tooth pressure per inch, face of gear and pinion, when pump is delivering 110,000,000 gallon per day at 65 foot head pounds 300
Gear ratio.. 10.53 to 1
Angle of gear tooth, degrees................................ 45
Mechanical efficiency of gear, per cent...................... 98
Horse power consumed by gear under maximum conditions... 31

Pump

Net weight of pump without bedplate, pounds	40,000
Net weight of bedplate for complete unit, pounds	15,000
Diameter of impellers, inches	50
Diameter of shaft at impeller, inches	8
Diameter and length of bearings, inches	One 6½ x 18, one 5¼ x 18
Length of shaft between bearings, feet	8½
Revolutions per minute, maximum	352
Diameter of water suction, inches	48
Diameter of water discharge, inches	48
Efficiency of pump, per cent (for normal conditions)	81

Condenser

Condensing surface, square feet	2825
Diameter of tubes, inches	1
Gage of tubes	No. 18 B. W. G.
Length of tubes, feet	12
Number of steam passes	1
Number of water passes	2
Size of exhaust-steam inlet, inches	36
Net weight of condenser, pounds	20,800
Diameter of condenser shell, feet	5
Length of shell, feet	14¾

Air pump

Revolutions per minute	115
Size of inlet, inches	5
Size of outlet, inches	3
Method of driving air pump	By steam cylinders
Weight of air pump complete, pounds	6400

Condensate pump

Size of pump, inches	2½
Revolutions per minute	1800
Size of inlet, inches	2½
Size of outlet, inches	2½

SOME PHASES OF WORK IN THE DISTRIBUTION SECTION OF THE WATER DIVISION, ST. LOUIS

By W. A. Foley

There are several distinct features of the St. Louis distribution system which do not usually obtain in other municipalities; principal among these may be mentioned the two distinct distributing systems called the high and low. The topography of St. Louis is such that the city maintains these two systems, the first termed high at 125-pounds pressure, the second termed low at 85-pounds pressure.

The low system comprises about 67 per cent of the pipe mileage, and ranges in size from 3-inch to 48-inch, amounting to 680 miles, supplying approximately 35.4 square miles of area. This system supplies certain districts where the elevation does not exceed 100 feet above the city datum. It was installed before the confining limits of the city were extended, when the city proper was located on the table land adjacent to the river.

As the city growth pushed forward it was essential that the outlying districts be supplied with an adequate volume and pressure, and the topography of the land was such that an increased pressure system with high duty pumps had to be installed to meet the demand. The high-pressure district now comprising 330 miles of pipe was decided upon. This system supplies districts in which the elevation exceeds the city datum by more than 100 feet, and is equal in area to 26 square miles. The two systems are separate and distinct, although there is contiguity in all the mileage, the pipe system being laid out on the gridiron theory. Each is maintained separate and independent of the other by means of valves, which close off one system from the other, thus maintaining the independent pressures. The valves are termed separation valves, being kept closed and tabbed with metallic disks showing the number of each valve and indicative of the valve being shut. In the event a metallic disk is not readily available the cap-nut of the valve is reversed or inverted, which is also indicative of a separation valve.

These valves are not opened except when necessity arises, and in this event the high pressure is allowed to bleed into the low system

during the period the occasion demands. They are also opened during the semi-annual inspection of valves, which occurs in May and November, when all valves in the two systems are examined and worked to insure their thorough fitness for any subsequent operation, or as a relief to the crowding of the high service pumps, which occurs during the night, when a few separation valves are opened to relieve the load.

Many of the consumers are so fortunately located that either high or low service is available for domestic supply. The low-pressure extremes range from 30 to 85 pounds, and the high-pressure from 40 to 125 pounds. The business section of St. Louis, being the oldest, is supplied by the low pressure system, but ordinarily good pressure is obtained, the average for the commercial district, which comprises 483 city blocks or 2¼ square miles area, being 45 pounds.

Another feature of the St. Louis distribution system is a 36-inch lock-bar steel main in 30-feet lengths with riveted joints, 26,700 feet in length, which crosses the heart of the city, and acts as a carrier for either high or low-service feed. This feeder has its origin in the central pumping station and can be operated from an 85-pound head with a delivery of 750,000 gallons per hour, or from an 125-pound head with a delivery of approximately 1,000,000 gallons per hour. The change in this trunk line from high to low service is effected by the operation of a few hand-operated valves immediately in front of the engine house and two hydraulically operated valves at the terminus of the steel main, practically 5 miles distant, where it is breeched into both systems by means of a Y connection. In times of emergency or excessive draught, this feeder serves as a reserve or reinforcement of either system. Many other communities accomplish practically the same purpose by speeding up pumps in times of fire, but the St. Louis steel line was designed with the purpose in view of acting as a composite carrier on either system, as the need arose.

The essential necessity of present-day distribution is conservative despatch. Mechanical appliances to supplant slow hand labor and the execution of repair work with speed are the chief features of distribution work. Although all water distribution departments have features in common, with reference to the general work, yet each individual system has some little appliance or method of repair which is a special feature of that particular system.

Portable pumps driven by air or gas, such as Los Angeles has in service, trench filling by cable drag or auto slip, have been employed

in St. Louis, not by the exact method employed by other communities, but by methods which prove more feasible here. During the winter, when frozen soil conditions make the excavation for repairs of broken mains excessive in cost, the St. Louis Department has found it practicable to use a blast pan, such as is employed by street repair gangs in asphalt surfacing. This proves an effective method of dissipating the frost and expediates the work of excavation, consequently effecting a saving of both time and labor. In the repair of mains 15 inches in diameter and larger where such repairs necessitate the employment of a sleeve, the department finds it expedient to employ what is known as a sleeve-spacer. This simple device is the idea of a local street service foreman, and has proved of great value in such work. The spacer is a sort of turn-buckle affair, which is slipped into position and tightened, so as to prevent movement of pipe when the sleeve is slipped into place, but it serves an ideal purpose in spacing the sleeve so that an even joint can be run around the pipe circumference. Usually four of these spacers are employed in the repair of mains 30 inches in diameter and larger. This device is worthy of adoption, especially where repairs are made in close proximity to a valve and its subsequent closing with its large pressure surface may cause a creeping of pipe at the space where sleeve has been employed.

Constant attention to every detail is becoming absolutely essential for the maintenance of a modern pipe system. Air patrols to release air pockets, constant overhauling of valves and other appurtenances, and absolute attention are the prices demanded in a modern system. Conservation of water by the insertion of valves, so that no great loss of water will result from the scarcity of these necessary valves when shuts are enforced on a distributing system through broken mains, is essential. In St. Louis the practice of lengthy shuts for repairs was common until five years ago. These shuts are generally made in a residential district, and the inconveniences are many. Not only does the application of frequent valves mean a conservation of water, but it means inconvenience for fewer consumers, and the convenience of the consumer is the essential feature in water distribution.

Not only does the city of St. Louis study and apply all principles which tend to the betterment of the system, but the department maintains an intelligence bureau holding school for one week's duration twice per year. At these school sessions all employes of the distribution system attend, especially the newcomers, who are fully initiated in the art of cutting pipe, yarning and pouring joints, caulking,

assembling hydrants and valves, rigging derricks, the use and names of various tools, and all other little details with which all distribution employes should be familiar. These sessions are generally attended by department engineers, and often the exchange of ideas proves as beneficial to the superiors as to the subordinates. The professor in charge is generally a graduate of the ditch, who has advanced step by step in the service, and is capable of showing the principle by actual demonstration. By teaching the employes the use of tools and allowing them to do the actual work in these practice sessions, the department has always on hand an adequate corps of capable men who can assume the different positions without crippling the service when the occasion demands. All large cities should adopt the idea as it familiarizes the employes with the different methods and use of tools, which proves of inestimable value to the department when "trouble-time" arrives.

REPORT OF COMMITTEE ON WAR BURDENS OF WATER WORKS IN THE UNITED STATES

The Executive Committee of the American Water Works Association undertook to collect, for presentation before the annual convention of the Association, at St. Louis, May 13–16, 1918, information concerning the effect of war conditions upon the construction, operation and maintenance of water works in the United States. Replies to its call for information were received from about fifty municipally and corporately owned water works plants in the U. S. It was impossible to prepare this material in useful comparative form for presentation to the convention. A committee was therefore appointed to do this, which now presents its report.

GENERAL FINANCIAL CONDITIONS FACED BY WATER WORKS

Water works have suffered large increase in construction, operation and maintenance costs, due to war conditions. Marked decline in net revenue has resulted.

These conditions began to be generally felt late in 1916, but it was not until the latter part of 1917 that they became serious. Water works employees were true to their tasks; the desirability and continuity of their employment tended to stay the advance in their wages, which lagged behind the general advance in wages paid to labor, by a period of eighteen months, more or less. Men working in contractors' forces, in munitions and allied works, had long enjoyed very substantial, and in some war industries, abnormal increase in wages, before the increase came to water works employees.

But the advance in labor cost to American water works has gathered force in the last six months, and it is the general opinion of municipal and corporate managers that additional increases are certain to come during 1918 and thereafter, if labor is to be held. It is certainly undesirable to replace old well-trained forces, familiar with these properties, with other labor not having this familiarity, in the effort to hold the wages at a point below the general local standard for similar service. The character of the service would suffer. Serious and conscientious effort has been made by water

works operators generally, to reduce construction and operating forces and expenses to a minimum. These reductions have in many cases gone beyond desirable limits, even to reducing the working efficiency of the properties.

The general situation is a very serious one, from the point of view of the public, and an anxious one for the managers of water works. Already it has shown itself in increasing difficulty, and in many cases impossibility, of attracting capital to water works for necessary betterments. Moreover, it is inevitable that the Capital Issues Board will scrutinize more and more closely the diversion of funds to water works needs, particularly where those needs are not involved by governmental activities.

Pressure will doubtless be brought to bear to force communities to husband their water supplies, by reducing waste, leakage, and even unnecessary consumption, in order to curtail unnecessary investment in plant thus made necessary. No doubt, here as abroad, there may come a time when the smaller works will be unable to extend their service during the duration of the war, unless government needs be concerned, but it would be most unfortunate if the activities of an important city or of communities with manifold industrial and commercial industries were to be thus circumscribed.

The menace of the situation lies in the increasing difficulty, under such conditions, of maintaining constantly a water service, safe from a sanitary standpoint, necessary for good fire protection service, and adequate to industrial, commercial and domestic needs.

It appears clear that average pre-war prices will never again be realized and that the purchasing power of money has declined permanently the world over, as a result of the war, and will never be fully recovered. Present prices, which on most water works materials are double pre-war prices, and on labor 25 to 50 per cent greater, will probably not hold permanently after the war. Nevertheless, the old prices will not return as a whole.

The difficulty of the situation faced by utility properties in this country was clearly indicated in a letter addressed by the Secretary of the Treasury, Mr. McAdoo, to the President, on February 15, 1918, transmitting several memoranda prepared by committees of the American Electric Railway Association, The National Electric Light Association, the American Gas Institute and the National Commercial Gas Association, in which he called attention to the existence of genuine apprehension regarding the adequacy, under

present conditions, of the service and rates of local public utilities; that increased wages and high costs of essential materials and supplies have affected them, as they have affected everybody else; and that united effort will be necessary in order to meet alike the requirements of public service, and the corporate financial needs upon which that service depends. Concluding his letter to the President, the Secretary said:

I earnestly hope that you may feel justified in expressing the conviction that the vital part which the Public Utilities Companies represent in the life and war-making energy of the nation, ought to receive fair and just recognition by state and local authorities.

President Wilson in his reply to Secretary McAdoo, dated February 19, 1918, said:

It is essential that these utilities should be maintained at their maximum efficiency, and that everything reasonably possible should be done with that end in view. I hope that the state and the local authorities, where they have not already done so, will, when the facts are properly laid before them, respond promptly to the necessities of the situation.

Public Utility Commissions and other similar regulatory bodies n the United States have already shown their appreciation of the serious nature of the conditions confronting public utility properties, by granting increases in rates or the levying of surcharges on existing rate schedules in many cases, after careful review of the local conditions.

Valuation under present conditions is a very difficult, laborious and time-consuming task, and in view of the heavy burden of additional work under which these commissions are laboring, it is reasonable to believe that prompter consideration can be had by petitioning for relief, rather than for revaluation of property as a basis for change in rates.

How far these commissions will attempt to maintain the standard, heretofore avowed by them, of taking prompt action, to the end of reducing the unfair burdens of the people on the one hand and the hazard of investment and operation on the other, cannot now be determined. They may take the position that a portion of the abnormal expense, due to war conditions, must be borne by the works and a portion by the public, but in any event, it appears likely that they will not be insensible to pleas fairly directed toward the maintenance of corporate credit, and will recognize clearly that

it is not to the interest of the public to permit conditions which may destroy credit, and that credit seriously impaired or once destroyed cannot be re-established readily.

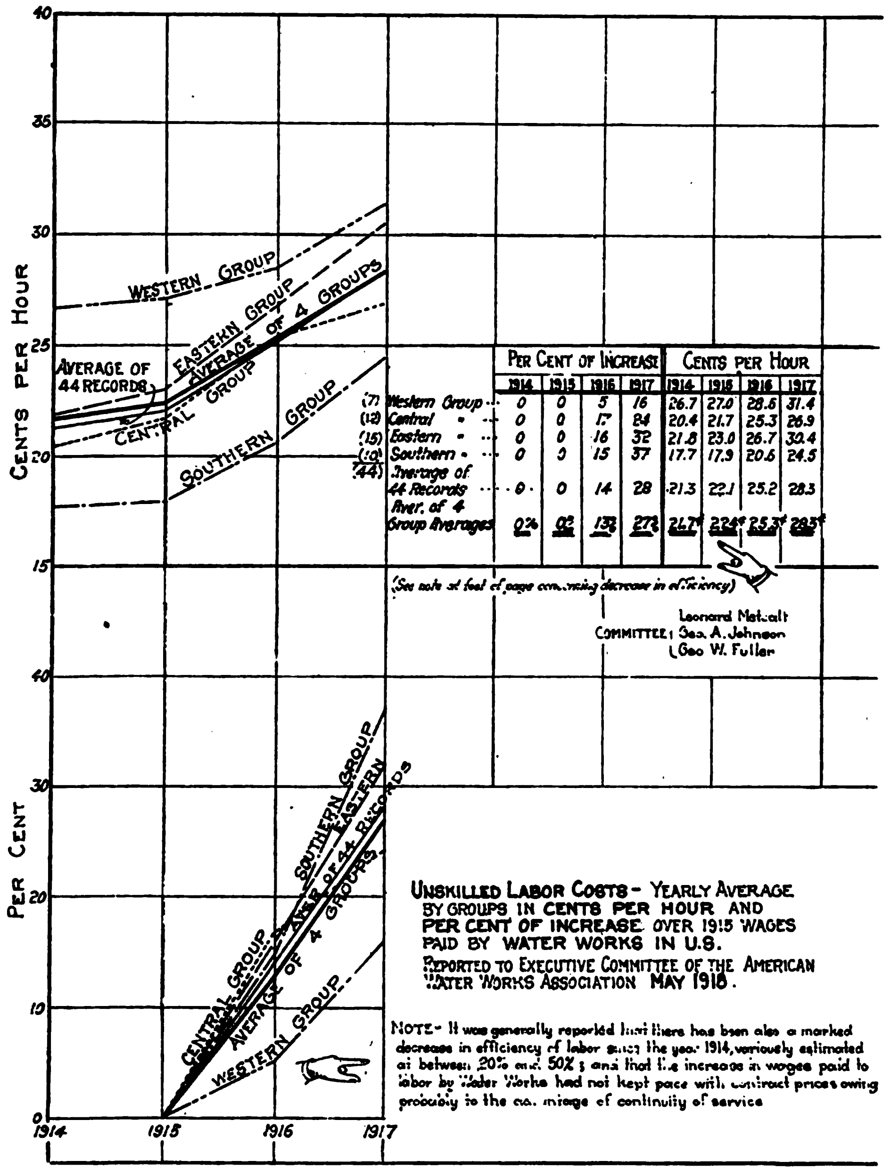
It was urged upon the members of the Association at the St. Louis convention, that the effort should be made to maintain operating efficiency, and that careful record should be made of change in cost of construction and operating materials and labor, so that if it should become necessary to make applications for advance in rates, on the part of either the municipally or the corporately owned works, the facts upon which the regulatory bodies could base sound judgment could be well established.

The following record of replies received from various municipally and corporately owned properties in this country, is submitted in tabular and graphical form, as evidence of the rapid change in conditions facing water works in this country from the years 1914 and 1915, which reflect the pre-war conditions, to the early part of the year 1918. All evidence points to yet more trying conditions for the future.

CONSTRUCTION LABOR AND MATERIAL COSTS

Advance in labor costs. Figure 1 shows the advance in the yearly average cost in cents per hour of unskilled labor to 44 American water works, arranged in four local groups. These indicate an average advance over pre-war prices prevailing in 1915 of 13 per cent in 1916 and 27 per cent in 1917, the fragmentary figures submitted for the opening of 1918 showing materially greater increase. It is important to note that comparison of past and present wage scales does not tell the whole story of increase in cost of labor to water works. Unfortunately, there has been marked decrease in efficiency. Your committee has made personal inquiry concerning this, within the last two months, from the managers of municipal as well as of corporate works, from the Pacific Coast to the East, and from the North to the South. In all cases, decrease in efficiency was reported. The estimates of percentage loss in efficiency, comparable with the efficiency of 1915 and prior thereto, varied from 20 to 50 per cent. The concensus of opinion seemed to range between 25 and 35 per cent.

It thus appears that the loss in efficiency of labor is practically equal to its increase in wage. The full increase in cost of labor,



	Per Cent of Increase				Cents per Hour			
	1914	1915	1916	1917	1914	1915	1916	1917
(7) Western Group	0	0	5	16	26.7	27.0	28.6	31.4
(12) Central "	0	0	17	24	20.4	21.7	25.3	26.9
(15) Eastern "	0	0	16	32	21.8	23.0	26.7	30.4
(10) Southern "	0	0	15	37	17.7	17.9	20.6	24.5
(44) Average of 44 Records	0	0	14	28	21.3	22.1	25.2	28.3
Aver. of 4 Group Averages	0%	0%	13%	27%	21.7¢	22.4¢	25.3¢	28.5¢

FIGURE 1

TABLE 1

Unskilled labor costs—average during year in cents per hour. Paid by water works in the United States

REFERENCE NUMBER	STATE	POPULATION IN THOUSANDS	1914	1915	1916	1917	1918
			Western group				
45	California	575.0	25–28.1	25–28.1	28.1–31.3	31.3–34.4	31.3–37.5
46	California	523.0					
52	Washington	350.0	37.5	37.5			50.0
51	Oregon	275.7	37.5	37.5	37.5	37.5	40.6
47	Colorado	213.4	22.5	22.5	22.5	30.0	35.0
50	Kansas	67.8	17.5	20.0	22.5	27.0	
48	Iowa	27.1	25.0	25.0	25.0	30.0	
49	Iowa	14.0	20.0	20.0	25.0	25.0	
Total			186.7	189.0	199.7	219.9	
Average			26.7	27.0	28.5	31.4	
			Central group				
25	Michigan	678.7	25.0	25.0	28.0	36.0	
20	Indiana	269.5	20.0	20.0	22.0	24.0	25.0
26	Illinois	72.1	25.0	23.3	27.0	30.0	
31	Wisconsin	45.5	15.0	25.0	30.0	35.0	
24	Indiana	25.2	22.5	22.5	25.0	25.0	
21	Indiana	20.3	20.0	20.0	22.5	20.0	
29	Wisconsin	14.6	17.5	17.5	27.5	25.0	
28	Wisconsin	10.9	22.5	22.5	24.2	28.5	32.5
30	Wisconsin	8.8	20.0	20.0	20.0	25.0	
22	Indiana	5.6	17.5	20.0	25.0	22.5	
23	Indiana	5.6	17.5	20.0	25.0	22.5	
27	Ohio	4.0	22.2	25.0	27.7	30.0	
Total			244.7	260.8	303.9	322.9	
Average			20.4	21.7	25.3	26.9	
			Eastern group				
15	Pennsylvania	1,683.7					
1	Massachusetts	745.1	25.0	25.0	25.0	30.0	30.0
18	Pennsylvania	333.0	19.7	19.5	21.1	24.5	
16	Pennsylvania	150.0	18.0	22.5	29.0	35.0	
4	Massachusetts	110.0	31.0	31.0	31.0	24.0	
5	Connecticut	109.0	25.0	25.0	28.0	31.0	34.0
10	New York	99.4					
14	Pennsylvania	40.4	22.2	22.2	30.0	30.0	
9	New York	36.9	25.0	25.0	25–30	30.0	30.0

TABLE 1—*Continued*

REFERENCE NUMBER	STATE	POPULATION IN THOUSANDS	1914	1915	1916	1917	1918
		Eastern group—Continued					
11	Pennsylvania	26.6	20.0	22.2	30.8	33.3	
8	New Hampshire	26.0	20.0	25.0	28.0	33.0	33.0
19	Pennsylvania	18.9	20.0	21.0	27.5	34.0	37.0
13	Pennsylvania	15.0	22.2	22.2	29.7	33.3	
12	Pennsylvania	15.0	17.5	18.5	22.5	30.0	
17	Pennsylvania	14.4	20.0	21.0	22.5	25.0	
7	New Hampshire	4.9	22.0	25.0	25–30	30–37.5	
6	Maine	4.6	20.0	20.0	20.0	20–25	25.0
2	Massachusetts	1.2	25.0	25.0	25.0	30.0	30.0
Total			327.6	345.1	400.1	456.3	
Average			21.8	23.0	26.7	30.4	
		Southern group					
41	Missouri	740.0	25.0	25.0	25.0	32.5	
37	Louisiana	372.0					
32	Alabama	174.1	15.0	16.5	18.0	22.5	
40	Missouri	84.0	19.0	17.5	18.5	20.0	
34	Florida	62.6					
42	Tennessee	58.6	13.5	13.5	20.0	20.0	
33	Arkansas	55.2	15.0	15.0	20.0	27.5	
43	West Virginia	43.6	17.5	17.5	20.0	25.0	
43	Virginia	38.6	12.2	15.0	20.0	25.0	
35	Kentucky	35.0	20.0	20.0	22.5	25.0	25.0
38	Missouri	33.0	19.5	19.0	20.0	25.0	
36	Kentucky	7.8	20.0	20.0	22.0	22.0	
Total			176.7	179.0	206.0	244.5	
Average			17.7	17.9	20.6	24.5	
Average			21.3	22.1	25.2	28.3	

Unskilled labor costs—information received too late to be included in the original table

REFERENCE NUMBER	GROUP	POPULATION IN THOUSANDS	1914	1915	1916	1917	1918
New York City	Eastern	5,359.					
3	Eastern	16.8	20.7	20.0	25.0	30.0	
10	Eastern	111.0	19.3	17.5	25.9	26.7	
20	Central	289.0	20.0	20.0	22.0	24.0	25.0
34	Southern	68.8	18.0	18.0	18.0	19.0	

TABLE 2

Labor costs in water works pipe extensions, repair work, etc., in the United States. Approximate average cost in cents per hour for skilled and unskilled labor (*combined*). *Found by taking from the pay rolls the total labor cost and dividing it by the man-hours involved* Prepared by Leonard Metcalf Feb. 22, 1918.

NOTE. Construction work has been seriously curtailed since 1914 and in most cases could not have been executed at the wage rates here shown, had it been necessary to enlarge the organizations of the works here shown.

LOCATION OF WORKS	POPULATION SERVED (APPROXIMATE)	AVERAGE NUMBER OF MEN (APPROXIMATE)	PRE-WAR CONDITIONS			1915	1916	1917	1918
			1912	1913	1914				
1. Milford, Mass.	16,000	7 to 23	22.6	22.7	21.6	21.0	25.4	30.8	3 mos. only
2. Worcester, Mass. (sewer department)	160,000	94 to 374	25.0	25.0	25.0	25.0	26.0	29.0	
8 hour day minimum wage here shown for Worcester									
3. Central N. Y.	100,000	21 to 95	21.5	26.2	24.1	21.3	29.2	31.0	
4. Central Pa.	330,000	26 to 35	20.6	21.5	21.7	21.8	23.6	24.5	
5. Western Pa.	100,000								
6. Central Ind.	275,000	52	20.9	22.0	22.0	22.0	24.5	26.2	27.3
7. Northern Ind.	30,000	17 to 36	24.8	24.8	24.8	24.8	29.2	31.5	38.2
8. Los Angeles	500,000	3700–7800	33.6	34.0	35.6	35.1	36.5	37.7	
Average of seven records above			24.2	25.2	25.0	24.4	27.8	30.3	
Average (of three years)				24.8		98.4%	112.2%	122.2	
9. San Francisco, Cal.	450,000								Jan.
Spring Valley Water Co.									
a In City Distribution Department		34 to 63 = 45 Aver.		36.0		34.6	38.5	42.3	42.8

b In Service and Meter Department		42 to 88 = 56	41.1	39.3	39.6	42.6	46.7
c In (San Mateo) Water Division		26 to 87 = 51	34.1	37.0	34.2	37.4	41.2
d In Alameda County		24 to 44 = 33	27.4	27.3	26.6	28.5	33.9
Average (a, b, c, d)		Average = 185	35.4	35.5	36.2	39.4	41.7
			100%	100.5%	102.2%	111.2%	118.0%
Common labor			(29.7)	(30.8)	(29.9)	(32.5)	(35.7)
f In Calaveras (Dam)		187 to 478 = 328	28.2	27.5	29.3	30.6	33.6
		Average = 513	31.0	32.0	31.7	34.3	36.9
			100%	103.2%	102.2%	110.7%	119.1%
Treating Calaveras figures as a separate item from the average Spring Valley Water Company figures, we have							
Average (9)			26.6	26.0	28.9	31.2	
			100%	97.8%	108.7%	117.2%	
Spring Valley Water Company			31.0	32.0	31.7	34.3	36.9
			100.0%	103.2%	102.2%	110.7%	119.1%

Conclusion. The average rate paid in cents per hour for skilled and unskilled labor (combined) upon the works here recorded, was in

1915 approximately equal to the rate of 1912–13–14;
1916 approximately 9 per cent above the rate of 1912–13–14;
1917 approximately 17 per cent above the rate of 1912–13–14;

And for the Spring Valley Water Company of San Francisco for

1915 and 1916 approximately 3 per cent above the rate of 1912–13–14;
1917 approximately 11 per cent above the rate of 1912–13–14;
January, 1918, approximately 19 per cent above the rate of 1912–13–14.

Note that these records give no indication of the *decrease in efficiency* which has taken place.

due to the combined effect of loss in wages and loss of efficiency, is approximately 50 per cent in excess of the pre-war costs and nearly as much over those of 1916.

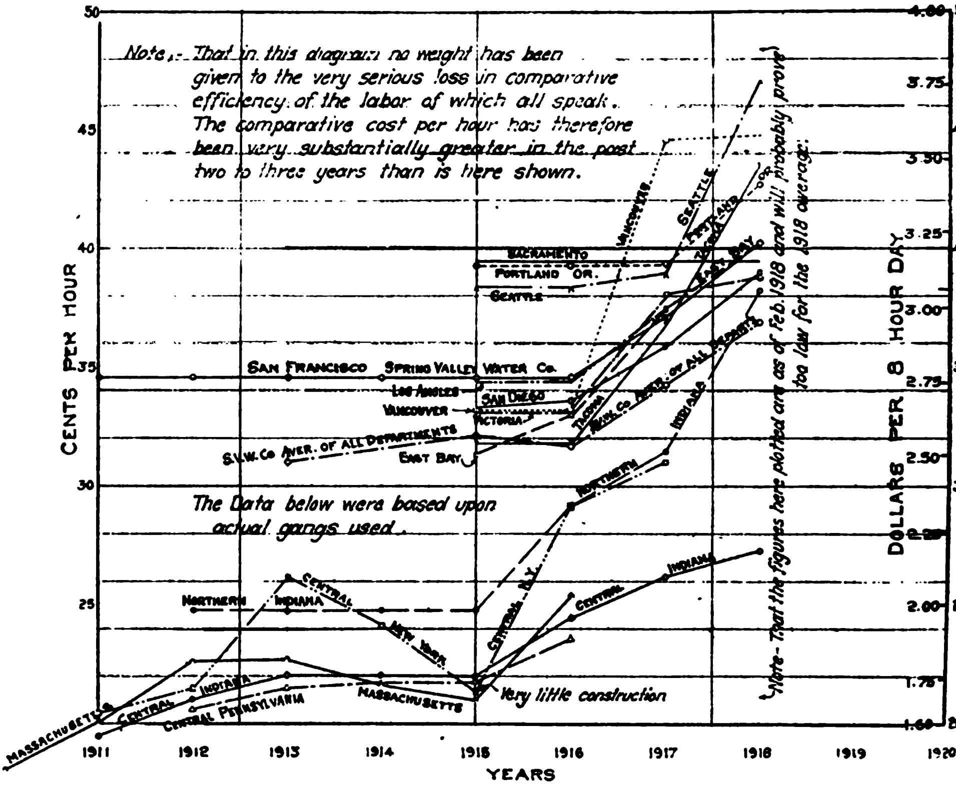


Fig. 2. Labor Costs per Man-Hour Paid by American Water-Works, Based upon the Actual Average Cost per Man-Hour of a Gang of 50 Men Comprising Foreman, Subforeman, 4 Calkers, 6 Pipe Layers, Blacksmith and 37 Laborers.

Similar data were gathered by one of the members of this committee at a slightly earlier date, with reference to the advance of labor costs in different parts of this country.

In figure 2, data relating to the central and eastern works were based upon the actual construction gangs used by the works referred

to; the data relating to the western works were based upon the normal gang, or gangs, totalling 50 men. Similar information to that relating to the eastern works was included with reference to the average cost of labor in all departments of the Spring Valley Water Company.

TABLE 3

Increase in cost of water works, cast iron pipe 6 inches and larger

REFERENCE NUMBER	STATE	POPULATION IN THOUSANDS	1914	1915	1916	1917	1918
			Eastern group				
4	Massachusetts	110.0	$22.13	$20.30	$27.10	$38.39	
5	Connecticut	110.0	22.60	21.70	31.00	59.00	$57.00
6	Maine	4.6	24.55†	26.78†			
7	New Hampshire	4.9	21.50†		34.93†		
8	New Hampshire	26.0	24.95	23.86	30.73	32.34	
9	New York	36.9	22.40	21.52	29.50	55.10	54.70
19	Pennsylvania	18.9	24.10	23.10	26.20	44.10	56.25
New York	New York	*	21.20	23.20	31.60	55.40	
Boston	Massachusetts		21.10	17.05	29.15	45.18	
Totals			158.48	150.73	205.28	329.51	167.95
Sub-averages			22.63	21.52	29.35	47.10	
			Central group				
25	Michigan	678.7	23.45	23.45	30.50	30.50	
28	Wisconsin	10.9	25.40	29.30	(†)	59.60	
Chicago	Illinois	..	24.10	24.50	31.80	54.60	
Totals			72.95	77.25	62.30	144.70	
Sub-averages			24.32	25.75	31.15	48.23	
			Southern group				
35	Kentucky	35.0	23.15	22.70	29.70	56.00	
37	Louisiana	372.0	21.00	22.50	22.50	56.00	53.00
41	Missouri	740.0	22.60	22.85	29.95	62.00	
Birmingham	Alabama		18.80	19.00	26.10	48.80	
Totals			85.55	87.05	108.25	222.80	
Sub-averages			21.39	21.76	27.06	55.70	

TABLE 3—*Continued*

REFERENCE NUMBER	STATE	POPULATION IN THOUSANDS	1914	1915	1916	1917	1918
			Western group				
45	California	575.0	30.60	30.59	38.01	62.50	62.20
47	Colorado	213.4	30.00	30.00	36.75	63.75	63.00
51	Oregon	275.7	30.21	29.48	33.95	45.27	63.50
52	Washington	350.0	30.75†				67.50
San Francisco	California		31.30	31.30	36.90	60.20	
Totals			122.11	121.47	145.61	231.72	256.20
Sub-averages			30.53	30.34	36.40	57.93	
Grand totals (18 works)			$439.09	$436.40	$521.44	$928.73	
Average				24.23	30.70	51.60	
Per cent of increase over 1915 costs					26.7	112.9	
			Data received too late to include in above table				
New York	New York‡	5,468.0	$20.45	$22.22	$31.14	$52.48	
3	Massachusetts		22.65	23.55	None bought	None bought	
10	New York		22.04	21.62	27.60	33.58	
20	Indiana		21.65	21.38	25.58	45.88	54.78
34	Florida		22.74	22.28	28.42	51.40	
46	California		31.30	31.30	39.00	57.70	64.10

* Market price given in *Iron Age*.
† Omitted from totals and averages.
‡ Department of Water Supply, Gas and Electricity.

The labor costs involved in maintenance and operation are covered in the discussion upon the increase in cost of operation and maintenance of water works.

Advance in cost of cast iron pipe. The increase in cost of cast iron pipe of 6-inch and larger diameter, reported to the Committee, is indicated in table 3, which shows an increase in prices over those of 1915 of 26.7 per cent in 1916, and 112.9 per cent in 1917. The corresponding figures for 1918 are too fragmentary for averaging, but indicate a slightly smaller increase over 1915 than did the 1917 figures, by reason of the stabilizing effect of governmental control. The difference is nearly negligible, however.

Table 4 shows similar data, obtained by C. C. Cray, purchasing agent of the Indianapolis Water Company, from Chicago, Columbus, Cincinnati, St. Louis, Terre Haute, Evansville, and for New York City and other cities, which were unfortunately received too late for inclusion in the unit figures and averages shown in table 3.

Advance in cost of valves and hydrants. The increase in cost of 6-inch valves to eleven water works, in different parts of the country, is indicated in table 5. It shows an advance in price of 13.1 per

TABLE 4

Prices paid for cast iron pipe in seven cities, f.o.b. destination, tons of 2000 lbs.

	1915		1916		1917		1918	
	Tons	Weighted average cost	Tons	Weighted average cost	Tons	Weighted average cost	Tons	Weighted average cost
Chicago, Ill.	27,765	$21.86	20,681	$27.54	15,255	$34.95		
Columbus, O.	2,606	21.50	950	30.51	1,238	43.23		
Cincinnati, O.	8,500	22.37	4,592	27.71	1,179	41.26		
St. Louis, Mo.	2,626	22.93	1,764	29.95	998	62.00		
Terre Haute, Ind.	47	21.28	357	29.59	37	54.35		
Evansville, Ind.	801	21.00	1,152	25.52	676	38.25		
Weighted average of 6 cities		21.82		28.47		45.67		
Indianapolis, Ind.	2,150	21.38	1,794	25.58	2,046	45.88	113	$54.78

cent in 1916, 71 per cent in 1917, and approximately 107 per cent in 1918, all as compared with pre-war prices.

Advance in cost of some other water works construction materials. In table 6 are shown data concerning the recent advance in cost of some other water works materials reported by C. C. Cray, purchasing agent of the Indianapolis Water Company; and in table 6a similar data reported by the Spring Valley Water Company of San Francisco.

TABLE 5

Increase in cost of water works valves and hydrants

	1914	1915	1916	1917	THREE MONTHS OF 1918
6-inch valves					
Eastern group (5)					
Massachusetts	$10.50	$10.50	$10.50	$15.00	
Connecticut	10.50	10.50	11.50	20.00	24.28
New York	11.80	11.80	13.00	16.50	
Pennsylvania	11.40	11.40	11.40	16.50	
Pennsylvania	13.85	13.30	13.30	17.75	21.50
Central group (2)					
Michigan	12.35	12.35	14.50	26.50	
Wisconsin	9.20	9.20	14.65	23.06	
Southern group					
Kentucky	12.50	12.50	12.50	16.50	
Missouri	11.40	11.00	12.95	20.60	
Western group					
California	6.714	7.618	10.501	14.01	
Colorado	12.80	12.80	14.20	24.00	
Grand Totals (11)	123.01	122.97	139.00	210.42	45.78[2]
Average (of 11)	11.18	11.18	12.64	19.13	23.20*
Per cent of increase over 1915			13.1	71.1	107.6
12-inch valves					
Connecticut	$31.00	$31.00	$34.50	$62.34	$74.08
Pennsylvania	44.65	36.55	45.10	64.65	60.20
Michigan	36.80	36.80	45.00	69.00	
Grand totals (3)	112.45	104.35	124.60	195.99	134.28[2]
Average (of 3)	37.48	34.78	41.53	65.22	69.00†
Per cent of increase over 1915			19.4	87.6	98.7
2-way hydrants					
1. Connecticut	$33.40	$33.40	$42.70	$54.75	
2. New York	26.70	26.50	28.00	49.78	$60.24
3. Pennsylvania	31.75	31.75	43.50	42.00	54.40
4. Kentucky	24.00	24.00	24.00	35.78	
5. Louisiana	20.00	20.00	21.65	35.10	
6. Missouri	23.75	24.49	26.40	41.40	
Totals (6)	159.60	160.14	186.25	258.81	114.64[2]
Average	26.60	26.69	32.04	43.13	53.90‡
Per cent of increase over 1915			20.1	61.6	102.0

TABLE 5—*Continued*

Data received too late to include in other table

REFERENCE NUMBER	1914	1915	1916	1917	THREE MONTHS OF 1918
6-inch valves					
Boston, Mass.					
New York, N. Y.		$11.30	$13.65	$22.83	
3	$9.00	9.00	13.00	None bought	
10	11.25	11.25	13.88	18.77	
20	21.65	21.38	25.58	45.88	$54.78
34	22.74	22.28	28.42	51.40	
46					
12-inch valves					
Boston, Mass.					
New York, N. Y.			$36.40	$58.33	
3					
10	$31.50	$31.66	33.22		
20	33.00	33.00	39.33	52.50	$63.00
34					
46					
2-way hydrants					
Boston, Mass.					
New York, N. Y.		$24.77	$31.15	$45.75	
3	$28.10	28.27	28.80	None bought	
10					
20	34.00	33.50	39.44	54.77	
34	32.00		28.10	51.40	
46					

Note:—For 1918, the average prices shown are for the first two or three months of the year only and are found by multiplying the 1917 average by the ratio of the sum of the items in 1918 to the sum of the corresponding items in 1917.

* Average of two items is $22.89.

† Average of two items is $67.14.

‡ Average of two items is $57.32.

TABLE 6

Weighted average cost of construction materials to the Indianapolis Water Company for 1915, 1916, 1917 and three months of 1918, and percentage increase over 1915 prices

ITEM	UNIT	1915	1916	1917	1918 THREE MONTHS	INCREASED 1917 OR 1918 OVER 1915
						per cent
1. Cast iron pipe	Ton	$21.38	$25.58	$45.88	$54.78	156
2. Cast iron fittings	100 lbs.	2.502	2.75	4.19		67
3. Pig lead	100 lbs.	4.469	6.555	10.77		141
4. Jute	100 lbs.	6.50	7.75	10.50		61
5. Valves, 6-inch	Each	11.25	13.88	18.77		67
12-inch	Each	33.00	39.33	52.50	63.00	91
6. Valve boxes	Each	1.60	2.03	2.35	2.72	70
7. Hydrants—2-way and steamer	Each	33.50	39.44	54.77		63
8. Corporation cocks, ¾-inch	Each	0.32		0.713	0.84	162
9. Stop boxes, 3-inch	Each	0.63	0.75	0.91	1.27	101
10. Brick, common	1000	8.00	8.50	10.50	13.00	62
11. Paving, common	1000	35.00				
12. Cement, Sacks inc	Barrel	1.80	1.959	2.207	3.00	66
13. ⅝-inch meters	Each	6.99	8.40*	9.86	10.50†	50
14. ¾-inch meters	Each	10.50		14.83		
15. 1-inch meter	Each	14.00		19.50		
16. 2-inch meters	Each	41.65		62.36	62.50†	
17. 3-inch meters	Each	70.80		85.00		
18. Lumber Y. P	M	26.00	33.00	37.50	44.00	69
19. Sand and gravel	Load					
20. Reinforcing steel	100 lbs.	2.55	3.15	3.50	4.00	57

* Few purchases.
† Quotations.

TABLE 6 a

Prices paid by the Spring Valley Water Company, San Francisco

MATERIAL	PRICE NORMAL	PRICE JANUARY, 1918	PERCENTAGE OF INCREASE	TOTAL PERCENTAGE OF INCREASE. WEIGHTED AVERAGE
Oil, fuel, per barrel	$0.70½	$1.45	106.0	99.5
Oil, cylinder, per gallon	.53	.86	36.5	
Packing, flax, per pound	.40	.81	102.5	
Tubes, boiler, per foot	.32	.84	162.0	
Valves, rubber, per pound	.70	.90	28.5	
Waste, cotton, per pound	.09	.15	66.5	
Oil, dynamo, per gallon	.36	.531	47.5	50.0
Waste, cotton, per pound	.09	.15	66.5	
Polish, metal, per gallon	.85	.90	6.0	
Cheese cloth, per yard	.03¾	.10½	180.0	180.0
Hay, per ton	18.00	30.00	66.5	66.5
Copper sulphate, per hundredweight	5.50	10.75	95.5	95.5
Paint, per gallon	.65	1.10	69.5	69.5
Hay, per ton	18.00	30.00	66.5	66.5
Asphaltum, per ton	12.50	17.60	40.0	74.0
Coal tar, per barrel	6.00	12.00	100.0	
Oakum, per bale	4.50	8.75	94.5	
Lumber, base	12.50	24.00	92.0	
Nails, per hundredweight	2.35	4.70	100.0	
Paint, per gallon	.65	1.10	69.5	
Paint, per gallon	.65	1.10	69.5	85.0
Lumber, base	12.50	24.00	92.0	
Nails, per hundredweight	2.35	4.70	100.0	
Paint, per gallon	0.65	1.10	69.5	69.5
Meter parts			20.0	60.0
Fittings, brass, per pound	.35	.57½	64.5	
Fittings, galvanized	List less 85%	List less 65 and 10%	110.0	
Covers, meters, per pound	.03½	.06¼	78.5	
Leather, per pound	.40	.70	75.0	
Picks, per dozen	6.50	12.75	96.0	

TABLE 6 a—*Concluded*

MATERIAL	PRICE NORMAL	PRICE JANUARY, 1918	PERCENTAGE OF INCREASE	TOTAL PERCENTAGE OF INCREASE, WEIGHTED AVERAGE
Shovels, per dozen	11.00	18.50	68.0	
Cutters, pipe, each	1.50	2.75	83.5	60.0
Stocks and dies, each	5.00	8.00	60.0	
Wrenches, each	.75	1.50	100.0	
Pipe, cast iron, per ton	35.00	62.00	76.5	
Fittings, cast iron, per pound	.03½	.06¼	78.5	
Lead, pig, per pound	.04¼	.07	65.0	
Jute, per pound	.06	.12	100.0	70.0
Coal, per ton	10.00	13.00	30.0	
Picks, per dozen	6.50	12.75	96.0	
Shovels, per dozen	11.00	18.60	68.0	
Bars, crow, per pound	.04	.10	150.0	
Fittings, brass, per pound	.35	.56½	64.5	
Fittings, galvanized	List less 85%	List less 65 and 10%	110.0	
Pipe, galvanized, per cubic foot	4.50	10.05	124.0	
Pipe, lead, per hundredweight	6.50	10.75	65.5	
Picks, per dozen	6.50	12.75	96.0	87.5
Shovels, per dozen	11.00	18.50	68.0	
Cutters, pipe, each	1.50	2.75	83.5	
Stocks and dies, each	5.00	8.00	60.0	
Wrenches, each	.75	1.50	100.0	
Leather, per pound	.40	.70	75.0	
Office furniture			40.0	
Stationery			50.0	40.0
Printing			33.0	
Office furniture			40.0	
Stationery			50.0	
Printing			33.0	50.0
Hardware, builders'			50.0	
Shellac, per gallon	1.28	3.20	150.0	
Janitor's supplies			50.0	
Lumber, per base	12.50	24.00	92.0	
Nails, per hundredweight	2.35	4.70	100.0	80.0
Fencing, per hundredweight	2.65	5.55	109.5	
Paint, per gallon	.65	1.10	69.5	

ADVANCE IN COST OF OPERATING SUPPLIES

Turning now to important typical operating supplies, such as coal and alum, yet greater increase in price has taken place.

Coal. The prices paid for coal by 41 important water works, table 7, indicate an advance in prices in 1916, 1917 and early 1918, over those prevailing in 1915, of approximately 15, 74 and 117 per cent, respectively. It is interesting to note the variation in the different parts of the country. The East suffered in far greater measure than the South and the West; the Central States in like measure with the Southern and Western states in the years 1916

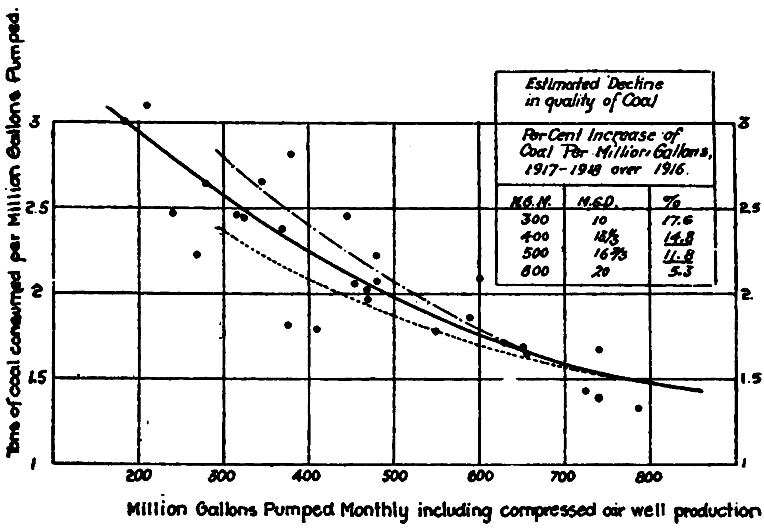


FIG. 3. PUMPAGE AND COAL FOR 28 MONTHS ENDING APRIL 30, 1918

and 1917, and in greater measure than any of the other groups in 1918. Incidentally, it may also be noted that the prices of fuel oil reported for one large plant in Louisiana and one in California show an advance in price in the opening of 1918 of approximately 150 per cent over those prevailing in 1915.

Unfortunately, in coal as in labor, the advance in unit prices does not reflect the entire increase in cost, inasmuch as decline in quality of the coal has been very generally observed. Effort was recently made to obtain exact information upon this subject by the Indianapolis Water Company through a study of the relative coal consumption per million gallons of water pumped during the past two years, or thereabouts. The results of this study, shown in figure 3,

TABLE 7

Increase in cost of water works fuel

REF. NO.	STATE	POPULATION IN THOUSANDS	COAL, DOLLARS PER TON					
			1914	1915	1916	1917	1918	
			Eastern group					
2	Massachusetts	1.2	$5.56	$5.56	$6.71	$11.21		
4	Massachusetts	110.0	4.18	4.20	5.33	10.00		
6	Maine	4.6	4.90	4.72	6.12	10.84	$12.00	
7	New Hampshire	4.9	4.38	4.39	5.04	8.05		
8	New Hampshire	26.0	4.80	4.90	6.75	9.00	9.00	
9	New York	36.9	3.45	3.45	3.85	6.48	7.65	
11	Pennsylvania	26.6	2.61	2.56	2.99	3.40		
12	Pennsylvania	15.0	1.21	1.24	1.68	2.55		
13	Pennsylvania	15.0	1.59	1.20	1.40	2.87		
14	Pennsylvania	40.4	1.27	1.45	2.84	3.67		
16	Pennsylvania	150.0	1.90	1.77	2.14	3.45		
17	Pennsylvania	14.4	1.82	2.08	3.33	4.33		
19	Pennsylvania	18.9	1.23	1.28	1.17	1.58	4.33	
Totals			38.90	38.80	49.35	77.43	32.98	Average of four items is $8.24
Sub-average of eastern group			2.99	2.98	3.80	5.96	7.04	

Central group

21	Indiana	20.3	2.02	1.91	1.96	2.55		
22	Indiana	5.6	1.21	1.11	1.77	2.87		
23	Indiana	5.6	1.25	1.25	1.86	3.13		
24	Indiana	25.2	1.83	1.94	2.16	2.90		
25	Michigan	678.7	2.29	2.21	2.37			
26	Illinois	72.1	1.34	1.49	1.88	2.67		
27	Ohio	4.0	5.40	5.32	5.40	5.34		
28	Wisconsin	10.9	2.89	2.87	2.67	3.85	6.55	
29	Wisconsin	14.6	2.32	2.18	2.73	4.82		
30	Wisconsin	8.8	3.52	3.51	4.53	5.45		
31	Wisconsin	45.5	2.75	2.72	3.17	4.45		
Totals			26.82	26.51	30.50	38.03	6.55	Average of one item is $6.55
Sub-average			2.44	2.41	2.77	3.75	6.38	

* Mine run screenings.

TABLE 7—*Continued*

REF. NO.	STATE	POPULATION IN THOUSANDS	COAL, DOLLARS PER TON 1914	1915	1916	1917	1918	
			Southern group					
32	Alabama	174.1	1.29	1.29	1.20	1.64		
33	Arkansas	55.2	2.33	2.31	2.46	3.34		
35	Kentucky	35.0	* 1.75 / 0.90	1.75 / 0.90	1.75 / 0.90	1.90 / 1.00	3.00 / 1.50	
36	Kentucky	7.8	1.88	2.55	2.61	4.52		
37	Louisiana	372.0	2.57	2.65	2.56	3.81	4.40	
38	Missouri	33.0	2.14	2.08	2.50	3.52		
39	Missouri	4.5	2.02	1.91	1.96	2.82		
40	Missouri	84.0	2.06	1.75	2.07	3.30		
41	Missouri	740.0	1.59	1.56	1.60	2.96		
42	Tennessee	58.6	1.69	1.64	1.92	3.39		
43	Virginia	38.6	2.99	2.85	2.92	5.30		
44	West Virginia	43.6	1.79	1.79	1.66	1.95		
Totals			25.00	25.03	26.11	39.45	8.90	Average of three items is $2.97
Sub-average			1.92	1.92	2.01	3.03	4.02	
			Western group					
45	California	575.0	9.50	9.50	9.50	16.50		
47	Colorado	213.4	4.05	4.05	4.60	5.00	6.25	
48	Iowa	27.1	1.87	1.95	2.61	3.73		
49	Iowa	14.0	1.85	1.90	2.00	2.55		
50	Kansas	67.8	2.50	2.44	3.16	3.76		
Totals			19.77	19.84	21.87	31.54	6.25	Average of one item is $6.25
Sub-average			3.95	3.97	4.37	6.31	7.89	

Average of all four group sub-averages

			DOLLARS PER TON					PER CENT OF INCREASE OVER 1915 COSTS		
								1916	1917	1918
Eastern group			2.99	2.98	3.80	5.96	7.04	27.5	100.0	138.3
Central group			2.44	2.41	2.77	3.75	6.38	14.9	56.4	164.7
Southern group			1.92	1.92	2.01	3.03	4.02	4.7	57.8	109.4
Western group			3.95	3.97	4.37	6.31	7.89	10.1	58.9	98.7
Average of group averages			2.82	2.82	3.24	4.77	6.33	14.9	69.2	124.4
Average of 41 works			2.63	2.62	3.04	4.52	5.69	15.3	73.7	117.1
Fuel oil, cents per gallon										
37	Louisiana	372.0	2.7	1.80	1.80	2.00	4.50	0.0	11.1	150.0
45	California	575.0	1.785	1.38	1.50	2.57	3.55	8.7	86.2	157.3

* Mine run screenings

NOTE. For 1918, the average prices shown are for the first two or three months of the year only and are found by multiplying the 1917 average by the ratio of the sum of the items in 1918 to the sum of the corresponding items in 1917.

TABLE 7—*Concluded*

Data received too late to include in table

REF. NO.	STATE	POPULATION IN THOUSANDS	COAL, DOLLARS PER TON				
			1914	1915	1916	1917	3 months of 1918
	Boston, Mass.						
	New York, N. Y.		2.93	2.86	3.55	6.06	
3							
10							
20				1.45	1.496	2.439	3.323
34							
46							
			Fuel oil, cents per gallon				
20				7.0	8.0	10.0	12.0

TABLE 8

Increase in cost of alum

REFERENCE NUMBER	STATE	1914	1915	1916	1917	1918
	Eastern group					
		cts.	cts.	cts.	cts.	cts.
6	Maine	1.33	1.78	3.37	2.30	2.33
7	New Hampshire	1.17	1.65	3.38	2.14	
11	Pennsylvania	0.985	0.985	0.985	1.345	
12	Pennsylvania	0.905	0.905	0.905	1.26*	
13	Pennsylvania	1.06	1.06	1.06	1.345	
14	Pennsylvania	0.87	0.87	0.87	1.225	
16	Pennsylvania	0.935	0.935	0.935	1.295	
17	Pennsylvania	0.96	0.96	0.96	1.245	
19	Pennsylvania	1.025	1.0	3.0	1.17†	1.30
	Central group					
22	Indiana	0.96	0.96	0.96	1.28	
24	Indiana	0.93	0.93	0.93	1.28	
26	Illinois	0.91	0.91	0.91	1.216	
29	Wisconsin	0.92	0.92	0.92	1.255	
30	Wisconsin	0.87	0.87	0.87	1.205	
	Southern group					
32	Alabama	1.20	1.20	1.20	1.50	
33	Arkansas	1.19	1.19	1.19	1.49	
35	Kentucky	0.575	0.575	1.12	1.100	
36	Kentucky	1.22	1.25	3.75	2.26	
38	Missouri	1.135	1.135	1.135	1.435	
39	Missouri	0.97	0.97	0.97	1.276	
40	Missouri	0.975	0.975	0.975	1.275	
41	Missouri	0.923§	0.923	1.136	1.271	
42	Tennessee	1.25	1.25	1.25	1.56	
43	Virginia	1.07	1.07	1.07	1.47	
44	West Virginia	0.935	0.935	0.935	1.26	
	Western group					
47	Colorado	1.30	1.30	1.45	1.75	1.75 (3 mos.)
49	Iowa	0.97	0.97	0.97	1.276	

TABLE 8—*Concluded*

REFERENCE NUMBER	STATE	1914	1915	1916	1917	PER CENT INCREASE OF COST OVER 1915	
						1916	1917
	Averages by groups						
	Eastern (9)......	1.027	1.116	1.718	1.481	54.0	32.7
	Central (5).......	0.91	0.91	0.91	1.247	0.0	37.0
	Southern (9).....	1.074	1.078	1.379	1.477	28.0	37.0
	Western (2)......	1.14	1.14	1.21	1.513	6.1	41.4
Average of group averages..............		1.038	1.058	1.304	1.429	23.3	35.1
Average of 25 works..		1.031	1.068	1.395	1.435	30.6	34.4
20	Indiana		0.861	0.936	1.479		
New York market price..................		1.55	2.08	4.63	3.57	123.0	71.6

In using these data, the effect of old contracts carrying over this period is to be remembered. The relation between the prices paid and the current market prices are indicated in the above tabulation.

indicate a decline in quality of the coal of from 10 to 15 per cent, broadly speaking. The results are characteristic, rather than precise.

Carleton E. Davis, chief of the Bureau of Water of Philadelphia, reports that at one of their main pumping stations the increase in coal consumption during the past twelve months or so was 17.3 per cent per million gallons pumped, because of the inferior quality of the coal. At other stations a change in the type of pump or character of fuel used makes a comparison impossible.

Advance in price of alum. The record of prices paid by water works for alum, in cents per pound, is interesting and significant. It is to be borne in mind, however, that it reflects the leveling effect of long-time contracts under a rising market. This is indicated by comparison (table 8) of the prices submitted, with the average New York market prices, quoted from the *Journal of Industrial and Engineering Chemistry.*

The figures submitted indicate an advance in 1916 and 1917 over the prices of 1915, of approximately 30 and 24 per cent, whereas the advance in the New York market prices over the 1915 scale,

was 123 per cent in 1916, and approximately 72 per cent in 1917, the decline in the latter reflecting governmental control.

Some other operation supplies. Table 9 shows prices for sundry operating and maintenance supplies paid by the Indianapolis Water Company, during 1915, 1916, 1917 and 1918, furnished by C. C. Cray, purchasing agent of the company.

TABLE 9

Prices paid for supplies used in operation and maintenance by the Indianapolis Water Company in 1915, 1916, 1917 and three months of 1918

ITEM	UNIT	1915	1916	1917	1918 QUOTATIONS	INCREASE OVER 1915
						per cent
1. Coal	Ton	$1.45	$1.496	$2.439	$3.323	129
2. Alum	100 lbs.	.861	.936	1.479	1.939	125
3. Chlorine gas	100 lbs.		12.50	12.50	15.00	20
4. Oil, engine	Gallon	.179	.195	.25	.35	95
5. Oil, H. P. cylinder	Gallon	.349	.35	.44	.555	59
6. Oil, L. P. cylinder	Gallon	.234	.25	.34	.555	137
7. Oil, linseed oil	Gallon	0.84	0.78	0.97	1.50	78
8. White lead	100 lbs.	7.50	9.80	11.50	12.25	63
9. Electric power	K.W.H.	.01 .0125	.01 .0125	.015 .0175	.015 .0175	50* 40*
10. Brass castings	Pound	.22	.35	.45	.50	127
11. Special cast iron casting	Pound	.0292	.0325	.0411	.0522	78
12. Steel boiler tubes 4 inches	Foot	.1675	.2285	.55	.60	258
13. Printing bills	1000	.76	1.23	1.42	1.91	151
14. Heat (M. H. Lt. Co.)	Year	*Cont.*	*Cont.*	25%	Increase	25*
15. Rags (instead of waste)	Pound	.05	.06	.07	.08	60
16. Gasoline	Gallon	.125	.175	.215	.25	100
17. Coal oil	Gallon	.07	.08	.10	.12	71

* Exclusive of demand charges.

Summary. In table 10 and figures 4 and 5 are summarized the increases in cost of labor and materials, already referred to.

TABLE 10

Summary of data upon increase in cost of labor and materials to water works in the United States is reported to the Executive Committee of the American Water Works Association, May, 1918

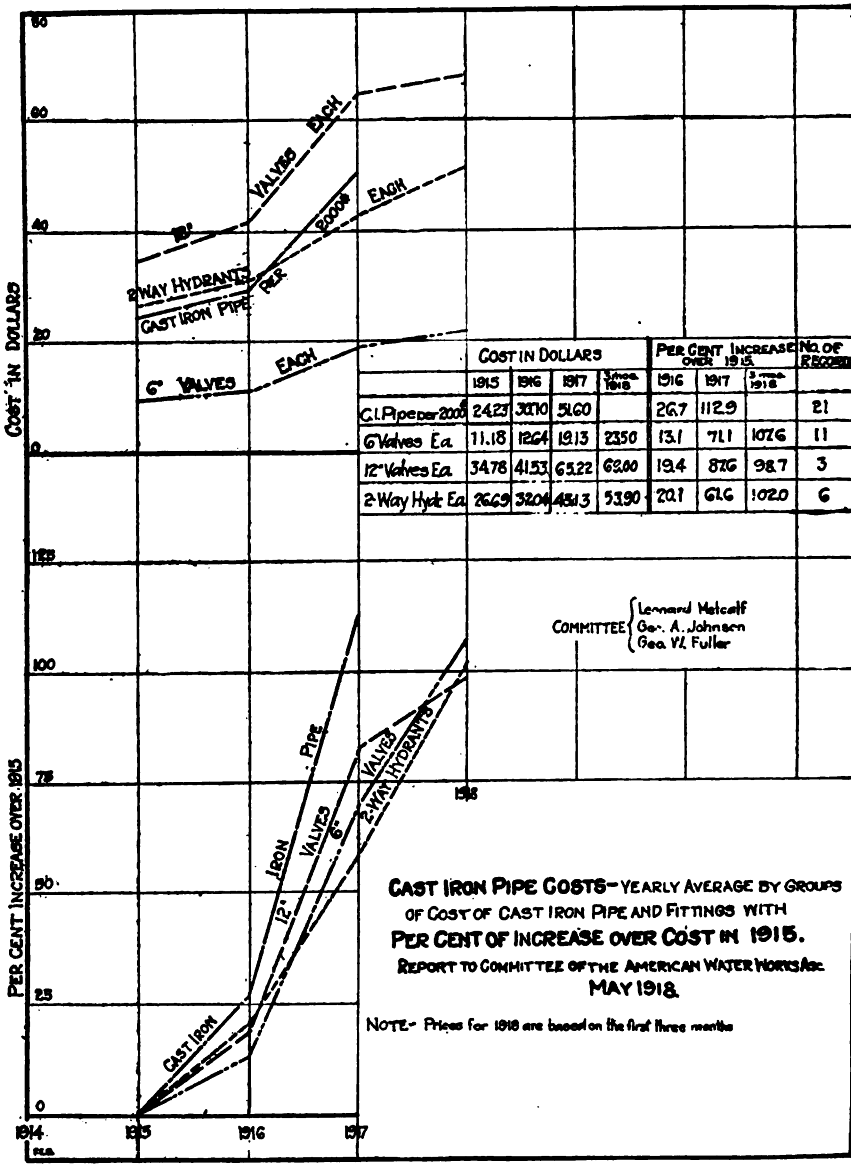
ITEM NO.	ITEM	NUMBER OF RECORDS	PRICES PER UNIT				INCREASE OVER 1915		
			1915	1916	1917	3 months 1918	1916	1917	3 months 1918
			cts.	*cts.*	*cts.*		*per cent*	*per cent*	*per cent*
1	Unskilled labor*—in cents per hour								
	a. Western group	7	27.0	28.5	31.4	Still in-	5	16	Still in-
	b. Central group	12	21.7	25.3	26.9	creasing	17	24	creasing
	c. Eastern group	15	23.0	26.7	30.4	in all	16	32	in all
	d. Southern group	10	17.9	20.6	24.5	groups	15	37	groups
	e. Average of groups (4)	—	22.4	25.3	28.3		13	27	
	f. Average of all	44	22.1	25.2	28.3		14	28	
2	Cast iron pipe—per 2000 lbs.	21	$24.23	$30.70	$51.60		26.7	112.9	
3	6-inch valves	11	$11.18	$12.64	$19.13	$23.20	13.1	71.1	107.6
4	12-inch valves	3	34.78	41.53	65.22	69.00	19.4	87.6	98.7
5	2 way hydrants	6	$26.69	$32.04	$43.13	$53.90	$20.1	$61.6	$102.0
6	Coal per 2000 lbs.								
	a. Eastern group	13	$2.98	$3.80	$5.96	$7.04	27.5	100	136.3
	b. Central group	11	2.41	2.77	3.75	6.38	14.9	56.4	164.7
	c. Southern group	12	1.92	2.01	3.03	4.02	4.7	57.8	109.4
	d. Western group	5	3.97	4.37	6.31	7.89	10.1	58.9	98.7
	e. Average of groups (4)		2.82	3.24	4.77	6.33	14.9	69.2	124.4
	f. Average of all	41	$2.62	$3.04	$4.52	$5.69	15.3	73.7	117.1

			cts.	cts.	cts.	cts.			
7	Fuel oil, cents per gallon..........	1	$1.80	1.80	2.00	4.50	0.0	11.1	150.0
	Fuel oil, cents per gallon..........	1	1.38	1.50	2.57	3.55	8.7	86.2	157.3
			cts.	cts.	cts.	cts.			
8	Alum, cents per pound								
	a. Western group..................	2	1.14	1.21	1.51		6.1	41.4	
	b. Central group..................	5	0.91	0.91	1.25		0.0	37.0	
	c. Eastern group..................	9	1.12	1.72	1.48		54.0	32.7	
	d. Southern group.................	9	1.08	1.38	1.48		28.0	37.0	
	e. Average of groups (4)..........		1.06	1.30	1.43		23.3	35.1	
	f. Average of all..................	25	1.07	1.40	1.44		30.6	34.4	
	g. New York market price†........	‡	2.08	4.63	3.57	5 mos 3.15	123.0	71.6	51.4

* NOTE. It was generally reported that there has been also a marked decrease in efficiency of labor since the year 1914, variously estimated at between 20 per cent and 50 per cent; and that the increase in wages paid to labor by Water Work had not kept pace with contract prices owing probably to the advantage of continuity of service.

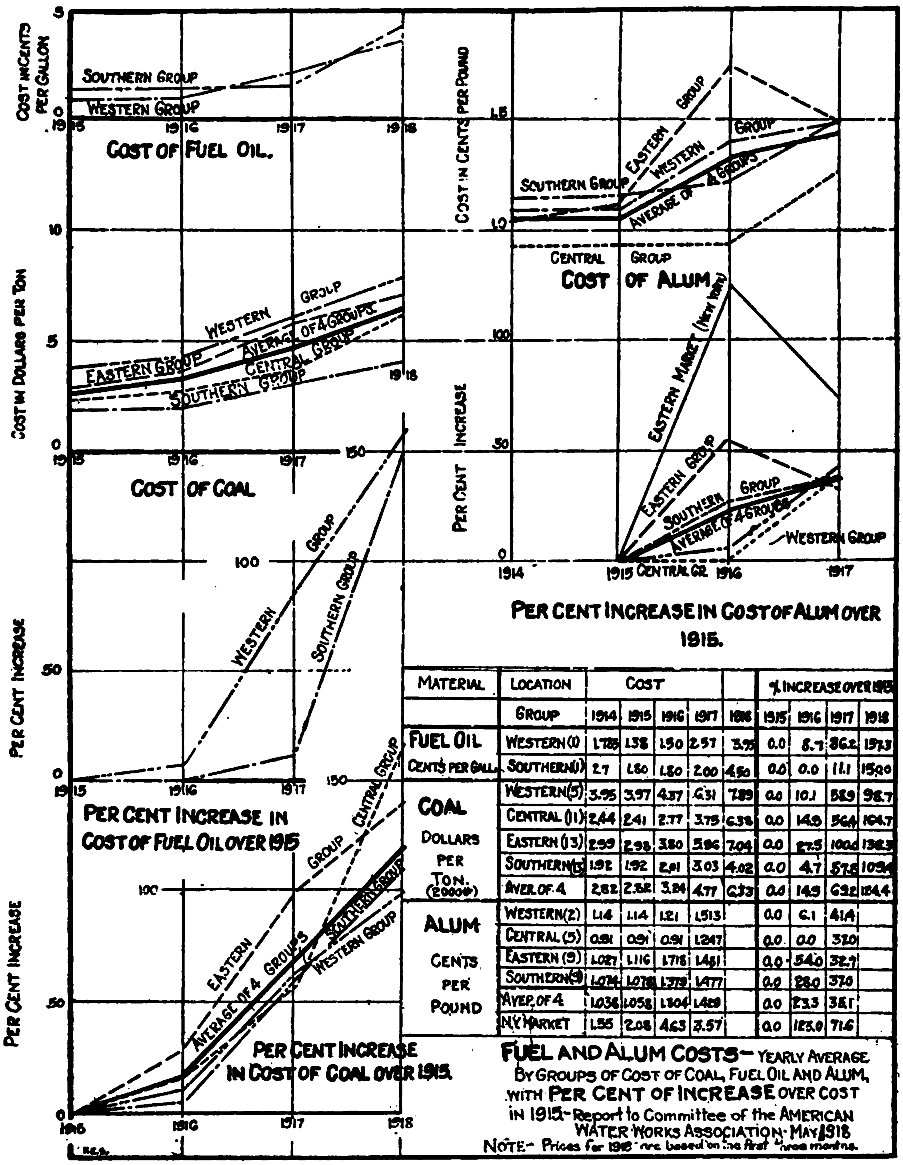
† *See Journal of Industrial and Engineering Chemistry.* Note that 1915 price was an advance of 34 per cent over the 1914 average price before the advances listed went into effect.

‡ Average of monthly prices.



	Cost in Dollars				Per Cent Increase over 1915			No. of Records
	1915	1916	1917	3 mos. 1918	1916	1917	3 mos. 1918	
C.I. Pipe per 2000#	24.23	30.70	51.60		26.7	112.9		21
6" Valves Ea.	11.18	12.64	19.13	23.50	13.1	71.1	107.6	11
12" Valves Ea.	34.78	41.53	65.22	69.00	19.4	87.6	98.7	3
2 Way Hyd. Ea.	26.69	32.04	43.13	53.90	20.1	61.6	102.0	6

FIGURE 4



MATERIAL	LOCATION GROUP	COST 1914	1915	1916	1917	1918	% INCREASE OVER 1915: 1915	1916	1917	1918
FUEL OIL CENTS PER GALL.	WESTERN (1)	1.785	1.38	1.50	2.57	3.95	0.0	8.7	86.2	157.3
	SOUTHERN (1)	2.7	1.80	1.80	2.00	4.50	0.0	0.0	11.1	150.0
COAL DOLLARS PER TON. (2000#)	WESTERN (5)	3.95	3.97	4.37	6.31	7.89	0.0	10.1	58.9	98.7
	CENTRAL (11)	2.44	2.41	2.77	3.75	6.38	0.0	14.8	56.4	164.7
	EASTERN (13)	2.99	2.98	3.80	5.96	7.04	0.0	27.5	100.0	136.3
	SOUTHERN (13)	1.92	1.92	2.01	3.03	4.02	0.0	4.7	57.8	109.4
	AVER. OF 4	2.82	2.82	3.24	4.77	6.33	0.0	14.9	69.2	124.4
ALUM CENTS PER POUND	WESTERN (2)	1.14	1.14	1.21	1.513		0.0	6.1	41.4	
	CENTRAL (5)	0.91	0.91	0.91	1.247		0.0	0.0	37.0	
	EASTERN (9)	1.027	1.116	1.718	1.481		0.0	54.0	32.7	
	SOUTHERN (9)	1.074	1.078	1.379	1.477		0.0	28.0	37.0	
	AVER. OF 4	1.036	1.058	1.304	1.489		0.0	23.3	38.1	
	N.Y. MARKET	1.55	2.08	4.63	3.57		0.0	123.0	71.6	

FUEL AND ALUM COSTS—YEARLY AVERAGE BY GROUPS OF COST OF COAL, FUEL OIL AND ALUM, WITH PER CENT OF INCREASE OVER COST IN 1915—Report to Committee of the AMERICAN WATER WORKS ASSOCIATION—MAY 1918

NOTE—Prices for 1918 are based on the first three months.

FIGURE 5

TABLE 11

Percentage of revenue and operating expenses of values for year 1915 for water works companies in the United States

Reference No.	State	Gross annual revenue in per cent of 1915						Operating expenses and taxes excluding depreciation in per cent of 1915						Operating revenue applicable to depreciation, interest, dividend and surplus in per cent of 1915					
		1913	1914	1915	1916	1917	Fraction of 1918	1913	1914	1915	1916	1917	Fraction of 1918	1913	1914	1915	1916	1917	Fraction of 1918
	Western group																		
45	California		102.3	100	126.0	115.5				100	125.6	120.5				100	126.3	113.5	
46	California		94.3	100	100.2	105.7			93.4	100	102.5	103.5	113.6		94.9	100	98.4	106.8	
47	Colorado		98.4	100	100.8	104.1			102.7	100	101.1	101.2			74.9	100	99.3	115.8	
48	Iowa		103.9	100	109.2	114.3			98.9	100	112.2	117.1			108.2	100	106.5	111.8	
49	Iowa		98.1	100	107.3	106.3			97.3	100	112.2	140.2			98.3	100	98.4	86.1	
50	Kansas		99.6	100	108.8	114.9			99.8	100	111.5	149.6			99.5	100	107.4	96.6	
51	Oregon		118.9	100	106.2	100.3			108.3	100	106.1	109.4			142.3	100	106.5	75.5	
52	Washington		98.1	100	100.2	115.0			89.9	100	198.6	97.6			107.7	100	90.5	135.9	
	Total..........		813.6	800	858.8	876.1			690.3	800	879.8	939.1			725.8	800	833.3	842.0	
	Average of group........		101.7	100	107.3	109.5			98.6	100	109.9	117.4	113.6		103.6	100	104.3	105.3	
	Average of records......		98.9	100	106.1	108.0			99.5*	100	106.5	105.8			94.5	100	105.8	110.3	
	Central group																		
20	Indiana		96.1	100	108.0	108.0	107.0		96.1	100	135.8	154.1	154.9		96.2	100	96.6	89.6	
21	Indiana		92.9	100	111.4	114.8			102.3	100	122.6	144.3			88.0	100	105.8	100.2	
22	Indiana		97.6	100	101.1	91.0			104.3	100	121.0	123.8			93.2	100	87.2	68.1	
24	Indiana		99.8	100	106.2	114.1			102.8	100	130.0	148.9			96.9	100	94.0	96.6	
25	Michigan																		
26	Illinois		100.6	100	112.3	117.9			90.6	100	114.9	132.1			107.5	100	110.6	108.4	

27	Ohio		80.7	100	126.1	131.0			88.6	100	128.0	157.5			61.0	100	122.1	65.7	
28	Wisconsin		101.7	100	105.5	120.4			96.3	100	102.2	130.5			109.3	100	110.5	111.5	
39	Wisconsin		96.1	100	101.6	101.3			99.2	100	114.2	133.4			94.2	100	92.8	77.8	
30	Wisconsin		94.1	100	112.0	111.3			121.0	100	124.0	135.0			63.5	100	99.4	84.6	
31	Wisconsin		97.6	100	116.3	118.2			95.9	100	126.1	151.0			99.0	100	111.1	101.8	
	Total		957.2	1000	1100.5	1128.0	107.0		997.1	1000	1218.9	1410.6			908.8	1000	1030.1	904.5	
	Average of group		95.7	100	110.1	112.8	107.0		99.7	100	121.9	141.1	154.9		90.9	100	103.0	90.6	
	Average of records		97.6	100	109.8	116.7			95.6	100	125.0	144.1			98.6	100	97.7	94.2	
	Eastern group																		
1	Massachusetts		101.6	100	105.5	100.3			100.7	100	103.5	119.2			102.0	100	106.5	90.4	
2	Massachusetts		95.3	100	106.0	102.4			101.2	100	99.1	114.1			90.2	100	111.4	92.2	
3	Massachusetts		97.2	100	100.4	100.8			114.8	100	113.0	129.6			84.7	100	91.9	80.7	
4	Massachusetts		94.5	100	108.1	105.8			96.8	100	123.1	139.0			91.4	100	87.6	84.9	
5	Connecticut	95.2	99.5	100	110.6	121.5		88.6	108.3	100	103.3	147.3		100.3	92.7	100	116.3	101.8	
6	Maine		109.6	100	114.6	126.3			101.8	100	102.1	119.6			128.8	100	145.1	143.1	
7	New Hampshire		98.9	100	102.8	105.6			85.6	100	114.4	118.5			110.0	100	93.2	94.8	
8	New Hampshire		100.0	100	102.2	106.2	109.8		100.2	100	90.8	101.8	114.1		99.8	100	111.7	110.3	105.9
9	New York		102.3	100	110.6	119.2	120.8		105.2	100	85.8	111.2	125.3		99.3	100	135.8	127.0	116.1
10	New York		98.1	100	108.7	114.9			110.2	100	100.0	117.6			94.3	100	111.5	114.0	
11	Pennsylvania		97.5	100	116.6	111.3			101.8	100	140.1	181.5			95.8	100	106.9	86.3	
12	Pennsylvania		103.8	100	110.6	114.2			103.3	100	117.9	170.6			102.0	100	105.6	81.2	
13	Pennsylvania		96.2	100	108.5	117.3			106.1	100	99.0	151.5			89.1	100	115.9	92.4	
14	Pennsylvania		93.1	100	120.0	109.0			89.2	100	124.4	177.1			95.6	100	117.4	67.7	
15	Pennsylvania																		
16	Pennsylvania		94.3	100	113.7	119.8			92.3	100	116.8	161.5			95.2	100	112.1	98.0	
17	Pennsylvania		102.2	100	101.1	109.5			104.6	100	127.8	183.6			101.3	100	90.6	80.0	

TABLE 11—*Concluded*

Reference No.	State	Gross annual revenue in per cent of 1915: 1913	1914	1915	1916	1917	Fraction of 1918	Operating expenses and taxes excluding depreciation in per cent of 1915: 1913	1914	1915	1916	1917	Fraction of 1918	Operating revenue applicable to depreciation, interest, dividend and surplus in per cent of 1915: 1913	1914	1915	1916	1917	Fraction of 1918
	Eastern group—continued																		
18	Pennsylvania		98.2	100	105.0	105.9			92.4	100	101.1	98.7			100.0	100	106.3	108.0	
19	Pennsylvania		85.1	100	111.2	124.3	129.6		103.1	100	104.1	131.5	181.0		89.1	100	115.6	119.6	97.2
	Total		1767.4	1800	1965.2	2014.3			1817.6	1800	1966.3	2473.1			1761.3	1800	1981.0	1772.4	
	Average of group		98.3	100	109.1	111.4			100.9	100	109.3	137.3			97.3	100	110.0	98.5	
	Average of records		97.8	100	105.0	105.5			100.8	100	95.9	112.7			96.5	100	105.7	95.8	
	Southern group																		
32	Alabama		106.7	100	111.8	125.2			98.7	100	99.6	120.4			112.2	100	120.3	128.4	
33	Arkansas		101.8	100	108.1	141.5			104.1	100	108.8	161.1			100.1	100	107.5	127.9	
34	Florida		98.4	100	106.8	110.4			101.4	100	115.3	135.1			96.9	100	99.0	93.5	
35	Kentucky		94.8	100	105.8	109.5			98.7	100	106.4	114.1			83.3	100	104.2	94.9	
36	Kentucky		106.6	100	104.0	114.8			111.1	100	112.7	133.8			100.8	100	92.7	90.2	
37	Louisiana		87.9	100	109.0	117.0			85.8	100	114.2	121.1			92.2	100	98.2	108.5	
38	Missouri		86.5	100	111.6	115.9			84.7	100	124.3	142.8			89.4	100	103.1	97.8	

39	Missouri		100.9	100	104.4	115.6			98.7	100	112.8	122.8			104.5	100	91.3	104.3	
40	Missouri		101.8	100	108.3	139.9			105.8	100	108.1	138.2			99.8	100	104.6	96.2	
41	Missouri	90.4	88.0	100	108.9	114.2		94.7	99.6	100	104.5	132.2		95.0	79.1	100	112.5	100.3	
42	Tennessee		97.2	100	109.5	130.2			98.0	100	112.3	160.1			96.6	100	107.7	108.1	
43	Virginia		97.7	100	103.4	121.7			95.1	100	113.0	158.0			98.0	100	97.1	99.8	
44	West Virginia		100.9	100	105.8	108.5			79.3	100	94.3	110.4			119.2	100	115.3	106.9	
	Total		1270.2	1300	1397.4	1564.4			1261.0	1300	1426.3	1750.1			1272.1	1300	1252.5	1356.8	
	Average of group		97.7	100	107.5	120.3			97.0	100	109.7	134.6			97.9	100	96.3	104.4	
	Average of records		93.8	100	109.0	115.0			97.0	100	111.0	130.0			90.2	100	107.0	105.0	

Summary of Groups. Per cent of 1915

Western		101.7	100	107.3	109.5			98.6	100	109.9	117.4			103.6	100	104.3	105.3	
Central		95.7	100	110.1	112.8			99.7	100	121.9	141.1			90.9	100	103.0	90.4	
Eastern		98.3	100	109.1	111.4			100.9	100	109.3	137.3			97.3	100	110.0	98.5	
Southern		97.7	100	107.5	120.3			97.0	100	109.7	134.6			97.9	100	96.3	104.0	
Total		393.4	400	434.0	454.0			396.2	400	450.8	530.4			389.7	400	413.6	398.2	
Average of groups		98.3	100	108.5	113.5			99.0	100	112.7	132.6			97.4	100	103.4	99.5	
Average of records		96.6	100	106.0	109.0				100	106.0	119.0			87.0	100	106.0	102.0*	

TABLE 11—*Concluded*

Data arriving too late to be included in original tabulation

	GROSS ANNUAL REVENUE IN PER CENT OF 1915				OPERATING EXPENSES AND TAXES IN PER CENT OF 1915				OPERATING REVENUE, APPLICABLE TO DEPRECIATION, INTEREST, DIVIDEND AND SURPLUS IN PER CENT OF 1915			
	1914	1915	1916	1917	1914	1915	1916	1917	1914	1915	1916	1917
Eastern group												
New York City	98.5	100	112	100.2		100	99	88†		100	103.5	105

In reviewing these statistics—which indicate that in spite of drastic curtailment of operating expenses, the normal growth in revenue necessary to carry the increase in investment, the net revenue, is on the average declining—the difference in position of the water works having to pump and filter their supplies as compared with those having unfiltered, gravity supplies is to be remembered. The former are feeling the greater financial burdens in much greater measure than the latter.

* Value would be lower if large western water works were omitted.

† Reduction in operating expenses due to reduced pumping after introduction of Catskill supply.

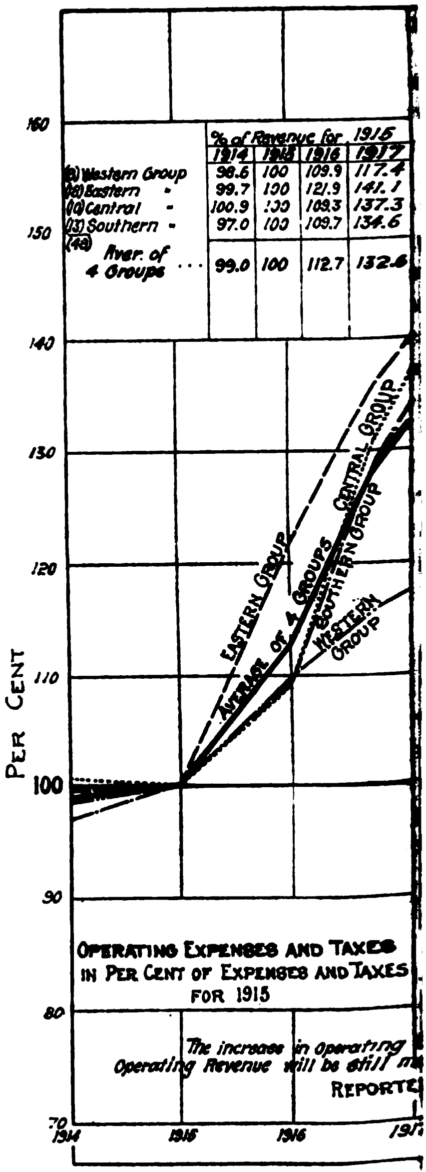

% of Revenue for 1915
1914 1915 1916 1917
(8) Western Group 98.6 100 109.9 117.4
(18) Eastern " 99.7 100 121.9 141.1
(10) Central " 100.9 100 109.3 137.3
(13) Southern " 97.0 100 109.7 134.6
(49) Aver. of 4 Groups . . . 99.0 100 112.7 132.6
160
150
140
130
120
110
100
90
80
70
PER CENT
EASTERN GROUP
CENTRAL GROUP
AVERAGE OF 4 GROUPS
SOUTHERN GROUP
WESTERN GROUP
OPERATING EXPENSES AND TAXES IN PER CENT OF EXPENSES AND TAXES FOR 1915
The increase in operating
Operating Revenue will be still m
REPORTE
1914
1915
1916
191

TABLE 11—*Concluded*

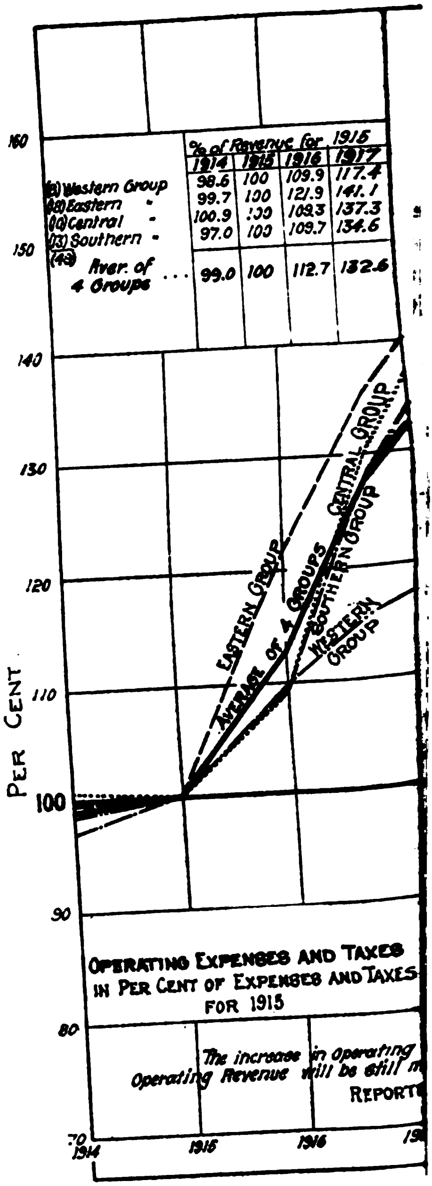
Data arriving too late to be included in original tabulation

	Gross annual revenue in per cent of 1915				Operating expenses and taxes in per cent of 1915				Operating revenue, applicable to depreciation, interest, dividend and surplus in per cent of 1915			
	1914	1915	1916	1917	1914	1915	1916	1917	1914	1915	1916	1917
Eastern group												
New York City	98.5	100	112	100.2		100	99	88†		100	103.5	105

In reviewing these statistics—which indicate that in spite of drastic curtailment of operating expenses, the normal growth in revenue necessary to carry the increase in investment, the net revenue, is on the average declining—the difference in position of the water works having to pump and filter their supplies as compared with those having unfiltered, gravity supplies is to be remembered. The former are feeling the greater financial burdens in much greater measure than the latter.

* Value would be lower if large western water works were omitted.

† Reduction in operating expenses due to reduced pumping after introduction of Catskill supply.



% of Revenue for 1915
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WESTERN GROUP
PER CENT
160
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120
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100
90
80
70
OPERATING EXPENSES AND TAXES IN PER CENT OF EXPENSES AND TAXES FOR 1915
The increase in operating
Operating Revenue will be still
REPORT
1914
1915
1916

WATER WORKS OPERATION AND MAINTENANCE COSTS

Returns were received from about fifty important water works concerning their gross annual revenue, operating expense including taxes but excluding depreciation allowance, and the resulting operating revenue applicable to depreciation allowance, fixed charges, dividends and surplus. These results have been analyzed and put into comparative percentage form, in order that the change in conditions might readily be understood. Inasmuch as a number of these records were given in confidential manner, with the understanding that the names of the corporations would not be mentioned, there has been recorded merely the state in which the works were located. The works have been assembled in four major groups, the western, the central, the eastern, and the southern, and are shown in table 11. A summary of groups gives averages for each of the groups and the average of the four group averages, and the averages of all of the records cited.

These records indicate, as do the construction records, that no marked change in conditions was felt until 1916; that the gross annual revenues for 1916 and 1917 were respectively 6 and 9 per cent in excess of those for 1915, but slightly more than those for 1914 on the basis of all of the records received, or 8.5 and 13.5 per cent on the basis of the average of group averages. The normal advance in gross revenue, corresponding to the growth in population and in investment, would probably have exceeded 6 per cent per annum and may have been substantially greater than this amount.

The increase in operating expenses over those of 1914–1915 was 6 and 19 per cent for 1916 and 1917, respectively, on the basis of all the records received, and 12.7 and 32.6 per cent on the basis of the average of the group averages.

The resulting operating revenues applicable to the depreciation allowance, fixed charges, dividends and surplus for 1916 and 1917, were respectively 6 and 2 per cent in excess of those for 1915, all on the basis of the average of all of the records received; and 3.4 and 0 per cent, respectively, in excess of 1915, on the basis of the average of the four group averages.

Broadly speaking, therefore, it appears from table 11, as from the graphical representation shown in figure 6, that the increase in operating expense has substantially absorbed the normal increase in gross revenue and has left no revenue to carry the burden of

TABLE 12

Data on increase in operating expenses of some American water works

Under date of May 31, 1918, F. C. Jordan, Secretary of the Indianapolis Water Company, wrote independently to a number of the leading water plants of the country, requesting information in reference to their increase in operating expense, and readjustment of rates to offset, in part, this increased cost of operation. Up to June 10, 1918, answers had been received from about forty or fifty of these cities. These answers indicate the following increases in operating expenses during the past six months, as compared with the normal pre-war operating expenses.

Increase over normal operating expenses

		REPORTED INCREASE
		per cent
1	Savannah, Ga	20
2	Richmond, Va	25
3	Milwaukee, Wis	36
4	Brockton, Mass	28.6
5	Champaign, Ill	30
6	Nashville, Tenn	25
7	Mobile, Ala	30
8	Philadelphia, Pa	35
9	Jamestown, N. Y	56
10	Toledo, Ohio	32
11	St. Catherines, Ont	25
12	Elmira, N. Y	33
13	Worcester, Mass	35
14	Paterson, N. J	16
15	Cincinnati, Ohio	25
16	Springfield, Ill	20
17	Springfield, Mo	25
18	Springfield, Mass	17
19	Peoria, Ill	25
20	Jersey City, N. J	15
21	Decatur, Ill	35
22	Cleveland, Ohio	31
23	Des Moines, Iowa	47
24	Schenectady, N. Y	20
25	Xenia, Ohio	33
26	Flint, Mich	18
27	Providence, R. I	52
28	Colorado Springs, Colo	25
29	Atlanta, Ga	40
30	Kansas City, Mo	35
31	Dayton, Ohio	21
32	Lansing, Mich	30
Average		29

TABLE 12—*Concluded*

Quite a number of the water departments have increased their water rates within the past year or so, and others report that they are petitioning for an increase or contemplate doing so in the near future. Among those that have increased their rates are the following:

Atlanta, Ga., reduced its discount for prompt payment from 25 per cent to 10 per cent.

Cincinnati, Ohio, increased its rates 25 per cent, this increase affecting all water consumers.

Dayton, Ohio, increased its annual minimum on $\frac{5}{8}$-inch meters from $4.40 to $6.60. This amount covers a quarterly consumption of 1000 feet in addition to the meter rental.

Flint, Mich., increased the rate to its large consumers from 5 cents per thousand gallons to 8 cents.

Brockton, Mass., increased its rates to all consumers.

Philadelphia, Pa., increased its metered water rates 30 per cent.

Richmond, Va., increased its rates to large consumers from $3\frac{3}{4}$ cents per thousand gallons to 5 cents.

Detroit, Mich., put into effect an increase covering all consumers, and is now considering an additional increase.

Toledo, Ohio, increased its water rates on October 12, 1916, and is now figuring on another increase.

Savannah, Ga., increased its rates to all water consumers.

Toronto, Canada, increased its rates 10 per cent in 1917, and an additional increase of 25 per cent became effective in the early part of this year.

The following cities are petitioning for increase, or contemplate doing so in the very near future: Champaign, Ill.; Davenport, Iowa; Hamilton, Ohio; Racine, Wis.; Springfield, Mo.; Tampa, Fla.; Worcester, Mass.; Kent, Ohio, etc.

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additional investments. There is marked decline in revenue in the eastern group, however.

Interesting similar data on increase in operating expense of some of the more important water works in the United States were obtained by Mr. Frank C. Jordan, Secretary of the Indianapolis Water Company, and are given in table 12.

SUMMARY OF FINDINGS

Records received from 50 typically important water works in the United States, indicate

(a) That the advance in the cost of labor used by water works in construction work during the past three years was approximately 13 per cent in 1916 and 27 per cent in 1917, over the pre-war costs

in this country. These pre-war costs were fairly reflected by prices prevailing in the year 1915.

Material decrease in efficiency of labor has also been observed in all parts of the country, the consensus of opinion indicating an approximate loss in efficiency of from 25 to 35 per cent.

(b) The important water works construction materials, pipe, valves, hydrants, etc., have more than doubled in cost.

The more important operating materials, such as coal and fuel oil, have also more than doubled and chemicals for the treatment of the water have advanced from 50 to 100 per cent and more.

(c) The normal annual increase in revenue of the water works of this country has in general decreased, except where war activities have materially increased the local market for water.

(d) The operating and maintenance expenses have increased approximately one-third, the increase in gravity works being of less serious moment generally, than in the pumping plants.

(e) The net revenues applicable to depreciation allowance, fixed charges, dividends, and surplus have, in general, remained about stationary, instead of increasing substantially from year to year, thus indicating that the new investment is not being taken care of, and that the divisible revenue is declining. The conditions vary markedly at individual plants and in groups, the eastern group showing the most marked decline in net annual revenues. Unfortunately the conditions are growing more and more serious.

CONCLUSIONS

First. That the water works of the United States have suffered, through war conditions, large increase in construction and operation costs.

Second. That marked decline in net revenue has resulted.

Third. These conditions did not begin to make themselves generally felt until late in 1916, and it was not until the latter part of the following year that they became serious. The desirability and continuity of employment tended to delay the advance in wages.

Fourth. The advance in cost of labor used in extension and minor construction work, by water works in this country, has gathered force in the last six months, and it is the general opinion of municipal and corporate managers that additional increases are certain to come during 1918 and thereafter, if labor is to be held.

Fifth. It is undesirable to replace old, well-trained forces, familiar with these water works properties, with other labor not having this familiarity, in the effort to hold the wages at a point below the general local standard for similar service. The character of the service would suffer and it would not be fair to labor.

Sixth. Serious and conscientious effort has been made by water works operators generally to reduce construction and operating forces to a minimum.

These reductions have in many cases already gone beyond desirable limits, even to reducing the working efficiency of the properties.

In other cases still greater economies are possible in better consumption of coal; waste reduction by increased use of controlling meters, pitometer surveys, and more frequent house to house inspection, and in quarterly instead of monthly meter readings of small meters.

Seventh. The general situation is a very serious one and has shown itself in increasing difficulty of attracting capital for necessary betterments. While extension of service is likely to be increasingly limited with the conditions of war, it would be unfortunate, if the activities of important industrial and commercial centers, particularly those concerned in governmental activities, should be thus circumscribed.

Eighth. The menace of the situation lies in the increasing difficulty under such conditions of maintaining constantly a water service safe from a sanitary standpoint, necessary for good fire protection service, and adequate for industrial, commercial and domestic needs.

Ninth. Public Service Commissions and other regulatory bodies have already recognized the danger of the present situation to the public as well as to the utilities, and are likely at least to afford such relief as may seem to them necessary to maintain credit, but it is imperative for water works operators to keep clear records, showing the actual change in conditions and prices of materials and labor, that these bodies may have uncontestable proof upon which to pass judgment as to the necessity for relief.

Tenth. It is imperative, in the interest of good service, that water works operators of municipally as well as corporately owned plants, should anticipate their construction and operation needs, as far as possible, and should be careful to obtain the necessary priority orders, that the quality of the water and the service rendered may

not be seriously impaired in the future for want of construction and operation materials and supplies.

Respectfully submitted,

LEONARD METCALF, *Chairman*,
GEORGE A. JOHNSON,
GEORGE W. FULLER.

PROGRESS REPORT OF COMMITTEE ON MECHANICAL ANALYSIS OF SANDS

The Committee on Mechanical Analysis of Sand has up to this time delayed the preparation of a report principally because of the fact that it is thought to be one of the principal duties of this committee to submit a proposed standard method of conducting such analyses and because during the past two years, especially, the United States Bureau of Standards at Washington, D. C., has been active in securing coöperation and joint action of parties interested in the selection and adoption of standard screens. It is recognized that standard screens are required not only for the mechanical analyses of sands but also in many other industries, yet it is believed that it is to the best interests of all having to do with such sand analyses that the one standard be used for all. There are obvious advantages in having the one standard screen scale available for all purposes and there is no apparent advantage in having a separate or distinct set of standard screens for testing sand.

Early action of the Bureau of Standards in the matter of standardizing sieves resulted in the adoption of certain specifications standardizing 200 and 100-mesh sieves used primarily for testing cement. Subsequently, early in 1917, responding to the demands of industry, the Bureau of Standards called a conference at Washington including representatives of practically all national engineering and technical organizations and others interested in the adoption of standard sieves. The conference, after considering various screen scales, adopted a standard screen scale and recommended that it be adopted generally by scientific, technical, and engineering societies and committees as part of their specifications for materials and methods of tests; also that it be used by private firms who have need of standard sieves. The committee recommends the adoption of the standard screen scale for sieves used in the mechanical analysis of sands.

The screen scale is essentially metric. The sieve having an opening of 1.0 mm. is the basic one and the sieves above and below this in the series are related to it by using in general the square root

of 2, or 1.4142, or the fourth root of 2, or 1.1892, as the ratio of the width of one opening to the next smaller opening. The first ratio, that is, 1.4142, is used for openings between 1.0 mm. and 8.0 mm., while the second ratio is used for openings below 1.0 mm. to give more sieves as required in that part of the scale.

Because of the possible wide range of openings in sieves now manufactured with a given number of meshes of wire per unit length, due to the use of wires of different diameters, and because of the consequent confusion and uncertainty which arise in designating sieves by the number of meshes per unit length, the sieves of this series are designated by the width of the opening in millimeters, as for example a 1.41 mm. sieve, or a 0.36 mm. sieve. The committee recommends that this method of designating sieves be adopted instead of the customary method of designating the number of meshes per inch.

To meet the need for sieves of this series at the present time the committee has included a temporary provision in the specifications for the acceptance of sieves of slightly different mesh and wire diameter than that called for in the screen scale, provided the resultant opening is the same as the nominal opening within a small range. This will make possible the use of a number of sieves now on the market in which the ratios of wire diameter to opening are only slightly different from those of the screen scale.

Specifications for standard sieves

Sieves shall be of brass constructed in diameters of 20 cm. (7.87 inches) or 15 cm. (5.91 inches). These are the outside diameters of the bottom of the sieves or the inside diameters of the top of the sieves.

Wire cloth for standard sieves shall be woven (not twilled, except that the cloth of 0.062-mm. sieves, may be twilled until further notice) from brass, bronze, or other suitable wire and mounted on the frames without distortion. To prevent the material being sieved from catching in the joint between the cloth and the frame, the joint shall be smoothly filled with solder, or so made that the material will not catch.

The number of wires per centimeter of the cloth of any given sieve shall be that shown in the accompanying table 1, in the second column, headed "Mesh," and the number of wires in any whole centimeter shall not differ from this amount by more than the tolerance given in the 5th column, that headed "Mesh" under the heading "Tolerances." No opening between adjacent parallel wires shall be greater than the nominal width of opening for that sieve by more than the following amounts:

Five per cent of the nominal width of opening for the 8-mm. to 1-mm. sieve inclusive.

TABLE 1

Standard screens for mechanical analyses of sand

	Width of openings	Mesh	Wire diameter	Ratio wire diameter to opening	Tolerances	
					Mesh	Diameter
Metric	8.00	1.00	2.00	0.25	0.01	0.008
Customary	0.315	2.54	0.079	0.25	0.03	0.003
Manufactured	8.05	2.5	0.083	0.26		
Metric	5.66	1.4	1.48	0.26	0.01	0.08
Customary	0.223	3.56	0.056	0.26	0.03	0.003
Manufactured	5.66	3.5	0.063	0.28		
Metric	4.00	2.0	1.00	0.25	0.02	0.05
Customary	0.157	5.1	0.039	0.25	0.05	0.002
Manufactured	4.04	5.0	0.041	0.26		
Metric	2.83	2.75	0.81	0.29	0.02	0.05
Customary	0.111	7.0	0.032	0.29	0.05	0.002
Manufactured	2.82	7.0	0.032	0.29		
Metric	2.00	3.9	0.56	0.28	0.04	0.05
Customary	0.079	9.9	0.022	0.28	0.1	0.002
Manufactured	2.03	10.0	0.020	0.25		
Metric	1.41	5.0	0.59	0.42	0.08	0.025
Customary	0.0555	12.7	0.0232	0.42	0.2	0.001
Manufactured	1.42	12.0	0.027	0.69		
Metric	1.00	7.0	0.43	0.43	0.15	0.020
Customary	0.394	17.8	0.0169	0.43	0.4	0.0008
Manufactured	1.01	18.0	0.016	0.41		
Metric	0.71	9.0	0.40	0.56	0.3	0.012
Customary	0.0280	22.9	0.0157	0.56	0.75	0.0005
Manufactured	0.72	22.0	0.017	0.60		
Metric	0.50	12.0	0.33	0.66	0.4	0.012
Customary	0.0197	30.5	0.0130	0.66	1.0	0.0005
Manufactured	0.50	3.0	0.0135	0.68		
Metric	0.36	16.0	0.26	0.72	0.6	0.010
Customary	0.0142	40.6	0.0102	0.72	1.5	0.0004
Manufactured	0.36	40.0	0.011	0.79		

TABLE 1—*Concluded*

	WIDTH OF OPENINGS	MESH	WIRE DIAMETER	RATIO WIRE DIAMETER TO OPENING	TOLERANCES	
					Mesh	Diameter
Metric	0.25	23.0	0.185	0.74	1	0.008
Customary	0.0098	58.4	0.0073	0.74	3	0.0003
Manufactured	0.25	60.0	0.007	0.72		
Metric	0.17	31.0	0.15	0.88	1	0.008
Customary	0.0067	78.7	0.0059	0.88	3	0.0003
Manufactured	0.17	80.0	0.00575	0.85		
Metric	0.125	47.0	0.089	0.71	1.5	0.008
Customary	0.0049	119.4	0.0035	0.71	4	0.0003
Manufactured	0.119	120.0	0.0036	0.77		
Metric	0.088	67.0	0.061	0.69	2.5	0.005
Customary	0.0035	170.2	0.0024	0.69	6	0.0002
Manufactured	0.089	170.0	0.0024	0.69		
Metric	0.062	98.0	0.040	0.65	3.5	0.005
Customary	0.0024	248.9	0.0016	0.65	9	0.0002
Manufactured	0.061	250.0	0.0016	0.67		

Ten per cent of the nominal width of opening for the 0.71-mm. to the 0.36-mm. sieve, inclusive.

Twenty per cent of the nominal width of opening for the 0.25-mm. to the 0.125-mm. sieve, inclusive.

Thirty per cent of the nominal width of opening for the 0.088-mm. and the 0.62-mm. sieve, inclusive.

The diameters of the wires of the cloth of any given sieve shall be that shown in the third column of table 1 headed "Wire Diameter," and the average diameter of the wires in either direction shall not differ from the specified diameter by more than the tolerance given in the last column of table 1, that under "Tolerances" headed "Diameter."

Sieves shall be rejected for obvious imperfections in the sieve cloth or its mounting, as for example, punctured, loose or wavy cloth, imperfections in soldering, etc.

Until further notice, to permit the use of sieves now on the market which have slightly different mesh and wire diameters from that specified above, sieves will be satisfactory if the measurements of mesh and wire diameters show the resulting average width of opening to be within 4 per cent of the nominal opening of a given sieve, and the ratio of wire diameter to opening of the sieve in question is within 0.03 of that given in table 1, in the column headed "Ratio Wire Diameter to Opening" for the 8-mm. to the 2-mm. sieves, inclusive, and within 0.06 of the ratio given for sieves of smaller openings than 2 mm.

The Bureau of Standards has announced that it will test sieves of the standard screen scale to determine whether they conform to the specifications which follow. This test will consist of an examination of the mesh of both the warp and shoot wires of the cloth to ascertain whether it comes within the tolerances allowed; also measurements of the diameter of wires in each direction to determine the average diameter; also a measurement of any large openings to determine whether they exceed the limits given in these specifications; also, an examination of the sieves to discover any imperfection of the sieve which may seriously affect its sieving value. Sieves which pass the specifications will be stamped with the seal of the Bureau and will be given an identification number and a certificate will be furnished for each sieve that passes the requirements.

For sieves which fail to meet the specifications reports will be rendered showing wherein the sieve was not up to the standard.

In the accompanying Table 1 the committee has shown the specifications for standard screens which it recommends for adoption by the Society. The first 7 sieves listed, that is from the 8-mm. to the 1.0-mm. sieve, include the first 7 sieves of the entire screen scale. For the sieves smaller than the 1.0 mm. sieve, only the alternate sieves of the screen scale are included.

In the table are shown the meshes per inch and diameters of wire, together with their tolerances, all expressed in millimeters and inches. Widths of openings are expressed also in millimeters and inches. There is also shown for each standard screen specifications for that sieve now manufactured which most nearly approaches the suggested standard screen, as regards width of opening and ratio of wire diameter to opening.

The committee wishes to call attention to the importance of the latter factor or ratio. Referring to the table, it will be observed that the ratio of wire diameter to opening varies from 0.25 to 0.88, generally increasing with the finer cloth. In practice it is found that the diameter of wire used should be as small as will withstand the service required, because material will not pass cloth composed of coarse wire so freely as it will pass cloth woven of fine wire. This fact undoubtedly is the principal reason why confusion has arisen in the past when it has been attempted to establish a relation between the diameter of opening and the size of the particle passing the opening, that is the separation of the sieve. For instance, in

the case of two sieves having the same width of opening, that in which the wire has the larger diameter will pass the larger particle, and vice versa.

Another feature of the manufacture of wire cloth which has considerable importance in affecting the separation of a screen is the weave. The finer screens are frequently made of twilled cloth, that is each wire crosses above and below each adjacent two wires, while in the plain woven cloth, each wire crosses above and below each adjacent wire. The plain woven cloth is always used for the coarser sieves. Experience shows that larger particles will pass through twilled cloth than through plain woven cloth of the same width of opening.

The committee recommends that the cloth in all of the standard sieves be plain woven and not twilled, although for the present it may be necessary to use twilled cloth for the 0.062 mm. sieve.

Methods of making mechanical analysis. A mechanical analysis of sand is generally accomplished in the following manner: The selected sieves are nested with the coarsest at the top varying to the finest at the bottom. For the 8 inch diameter sieves 300 grams and for the 6-inch sieves 100 grams of the sand to be analyzed are dried and placed in the top sieve, the nest of sieves is shaken in a mechanical shaker practically to refusal of any further separation, the sieves separated, and beginning with the finest sieve the sand remaining on each sieve is weighed accumulatively. The results are then plotted to a suitable scale.

There are six factors which control the results of a mechanical analysis, as follows: the selection of a representative sample; the quantity of material taken for analysis; the number and rapidity of the shakes; the accuracy of the weights of the separated portions; the rating of the sieves to determine their separations; and finally, the interpretation of results. Each of the above features has an important bearing on the accuracy and reliability of a mechanical analysis and should be given proper consideration.

The material to be analyzed should preferably be in its natural moist condition when sampled as otherwise it tends to separate. When dry it should be handled with a scoop and thoroughly mixed. In sampling a pile of moist sand a large sample should first be taken of several portions from different parts of the material, these portions mixed, the resultant sample quartered and the process continued until finally there is secured a sample of the required size.

The amount of sand used should be as large as practicable. For the 8-inch sieves 300 grams of graded sand and for the 6-inch sieves 100 grams may well be used. More than these quantities tend to stretch and clog the cloth and are not readily separated by shaking.

A mechanical shaker is required, especially where a large number of analyses are to be made. Several satisfactory machines are on the market. The essential feature of such a machine is that its speed shall be properly controlled. Experience will readily indicate the period of shaking required in the machine which should be operated by trial, using the required amount of sand until there is practically no further passage of sand grains through the screens.

In the case where a mechanical shaker is not available, as in field work, hand shaking when carefully executed will give results commensurate with a mechanical shaker. Experience indicates that when using the portions of sand indicated above, hand shaking for about 200 double horizontal shakes will give a satisfactory separation.

The accuracy of the weighing depends upon the precision of the balance used. Weights should be taken to 0.1 gram, with the understanding that the weights may be slightly in error when the total weight is greater than 100 grams.

The interpretation of a mechanical analysis depends primarily upon two features, the size of separation as determined for each sieve and the method of plotting and recording results.

At least two methods are available to determine directly the separation of a sieve, either to measure the three principal diameters of representative sand grains and to compute their average diameter or to count and weigh the grains and to compute the volume of the average particle obtained by dividing the weight of the average grain by its specific gravity. There is thus obtained the mean volume of the average grain which is considered to be a sphere and its diameter computed and taken as the separation of the sieve. The former procedure is recommended as giving the best results for large gravel; also for the extremely small grains of sand such as will pass a sieve of 200 meshes to the inch. A pair of calipers may be used to measure the diameters of the larger particles and a microscope to measure the smaller particles. The second procedure is the one commonly used for sieves ranging from 4 to 140 meshes per inch and requires the accurate separation of the sample, the counting and weighing of the grains and the determination of the specific

gravity of the grains. It will be observed that the rating of a nest of sieves in this manner is at best a tedious and difficult procedure.

Whatever the method used in determining the sizes of the grains the securing of an accurate sample is of first importance. The procedure is as follows: a sample of sand is put through the sieve in exactly the same manner as in making a mechanical analysis. Each sieve is then shaken a little by hand and the last particles going through are shaken over the next finer sieve. The last material remaining on the next finer sieve is considered the separation of the sieve.

Experience indicates that the results of the determinations of the sizes of separation are dependent almost entirely upon the selection of proper samples, because two determinations of the separation of a sieve using portions of the same sample should give the same results to the required accuracy when reasonable care is used. Owing to characteristic variation in the sizes and shapes of the grains it is desirable to use several kinds of sand from different locations or sources in order to determine the average separation. Where sieves are required largely for the mechanical analysis of a particular sand the procedure may properly be limited to determinations of the sizes of separation with this material only.

A comparative method of rating sieves also suggests itself in the event that there is available a nest of sieves already rated. A representative sample of sand may then be analyzed in the usual manner by the rated sieves and again may be separated into weighed portions by the unknown sieves. By plotting the percentages of the total weight on the curve of the analysis as determined by the first set sieves, the separations of the unknown sieves may be read directly. The comparative method has obvious advantages and in general is one of the methods now used by the Bureau of Standards to test 100 and 200 mesh cement sieves.

Because the method of rating a nest of sieves by counting and weighing the grains is a very tedious and expensive procedure, investigations have been made from time to time to determine whether or not there is any definite relation or relations between the width of opening of a screen and the size of separation. In view of the fact that in the past screens have been made with little if any attention to definite specifications or tolerances of mesh and diameters of wire it is not surprising that these investigations were not satisfactory and did not indicate whether or not such a relation exists.

Part of the difficulty undoubtedly was attributable to the personal factor and also to the use of grains of sand of different degrees of sharpness.

In table 2 are shown the openings of the standard screens and the probable sizes of separation that may be obtained with sieves built under the accompanying specifications, especially in regard to tolerances of mesh and diameter of wire. Experience indicates that

TABLE 2

Relation between sizes of opening and sizes of separation of sieves

SIEVE OPENING	MESH	RATIO WIRE DIAMETER TO OPENING	RATIO SIZE OF SEPARATION TO OPENING	CORRESPONDING SIZE OF SEPARATION
mm.	*inches*			*mm.*
8.00	2.54	0.25	1.09	8.72
5.66	3.56	0.26	1.09	6.17
4.00	5.1	0.25	1.09	4.36
2.83	7.0	0.29	1.09	3.08
2.00	9.9	0.28	1.09	2.18
1.41	12.7	0.42	1.10	1.55
1.00	17.8	0.43	1.10	1.10
0.71	22.9	0.56	1.10	0.78
0.50	30.5	0.66	1.10	0.55
0.36	40.6	0.72	1.11	0.40
0.25	58.4	0.74	1.11	0.28
0.17	78.7	0.88	1.11	0.19
0.125	119.4	0.71	1.11	0.14
0.088	170.2	0.69	1.11	0.10
0.062	248.9	0.65	1.20*	0.07

* Ratio assumed for twilled cloth. For plain woven cloth ratio is 1.11 and separation is 0.068 mm.

many sieves used for the mechanical analyses of sand would not come within these specifications especially because the spacing of the wires in one direction is not correct and within these specifications. Moreover it is not uncommon to find the wires used in the cloth to be of larger diameter and unsatisfactory on this account.

The Committee is not in accord as to the value of factors to be applied to determine the separation of a sieve with relation to its average width of opening. It is obvious, however, that the use of the accompanying specifications should result in a material improvement in the manufacture of testing screens; also that the use of such factors would be of great assistance in many cases in determining

the relation between analyses made by different investigators and expressed by either one of the two standards of measurement. Moreover, it is apparent that the use of the standard screens in specifications of material required has obvious advantages as compared with the use of such terms as will define the sizes of the particles, or of selected arbitrary percentages by weight of the particles.

Furthermore, the Committee is not in accord as to the standard of measurement which can best be adopted for rating sieves required for the mechanical analysis of sand. It is of course true that the principal use of such analyses, so far as this Association is concerned, is for the determination of the characteristics of sand required or used for filtration purposes. Moreover, up to the present time, the standard of measurement has been the size of separation of a sieve and not the width of opening. The screen scale now recommended by the Bureau of Standards for adoption is based upon the width of opening and not upon the size of separation. The committee is not yet prepared to report upon the adoption or uses of either standard of measurement because further investigation is required to reach a conclusion in this matter.

PHILIP BURGESS, *Chairman.*

AMENDMENTS TO THE CONSTITUTION[1]

AMENDMENTS TO ARTICLE III

This amendment qualifies for Active Membership, engineers, chemists, and other technical men, who act as such for, and are employed by, Associate Members of the Association. It is felt that in the past numerous persons well qualified for Active Membership have been improperly debarred from that grade through their employment by Associate Members. Section 3 as amended follows:

SECTION 3. An active member shall be either a superintendent, manager, or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, chemist or bacteriologist, including those acting technically as such for, and employed by, Associate Members of the Association; or any qualified person engaged in the advancement of knowledge relating to water supplies in general.

AMENDMENT TO ARTICLE VI

This is a highly important amendment affecting the manner of electing officers of the Association. The proposed amendment seeks to evenly balance the control of Association affairs by dividing the membership into six districts, each of which will have approximately the same number of members, and according to the plan herein proposed each of these six districts will always have representation on the Executive Committee. No one of the districts will be represented by more than one Trustee at any time. The term of office of Trustees will be three years in each case, two being elected each year in the districts in which the terms of the incumbents expire.

The new method of electing the Nominating Committee herein proposed is believed to be a marked improvement over the present. It provides that at the Annual Meeting each district shall submit one name, but not more than two, as candidates for the Nominating

[1] Submitted by the Special Advisory Committee, approved by the Executive Committee, December 1, 1917, and adopted by the St. Louis Convention on May 14, 1918.

Committee from that district. The names so submitted at the Annual Meeting, together with any others sent to the Secretary within sixty days after the Annual Meeting, are to be printed on a ballot and mailed to the voting membership of each district. Voting is not restricted to such names. Balloting on the election of members of the Nominating Committee follows in the same manner as that provided for the election of officers. The candidates receiving the largest number of votes for membership on the Nominating Committee thus selected by their respective districts, and the latest living past-President of the Association, are then formally appointed by the Executive Committee as the Nominating Committee.

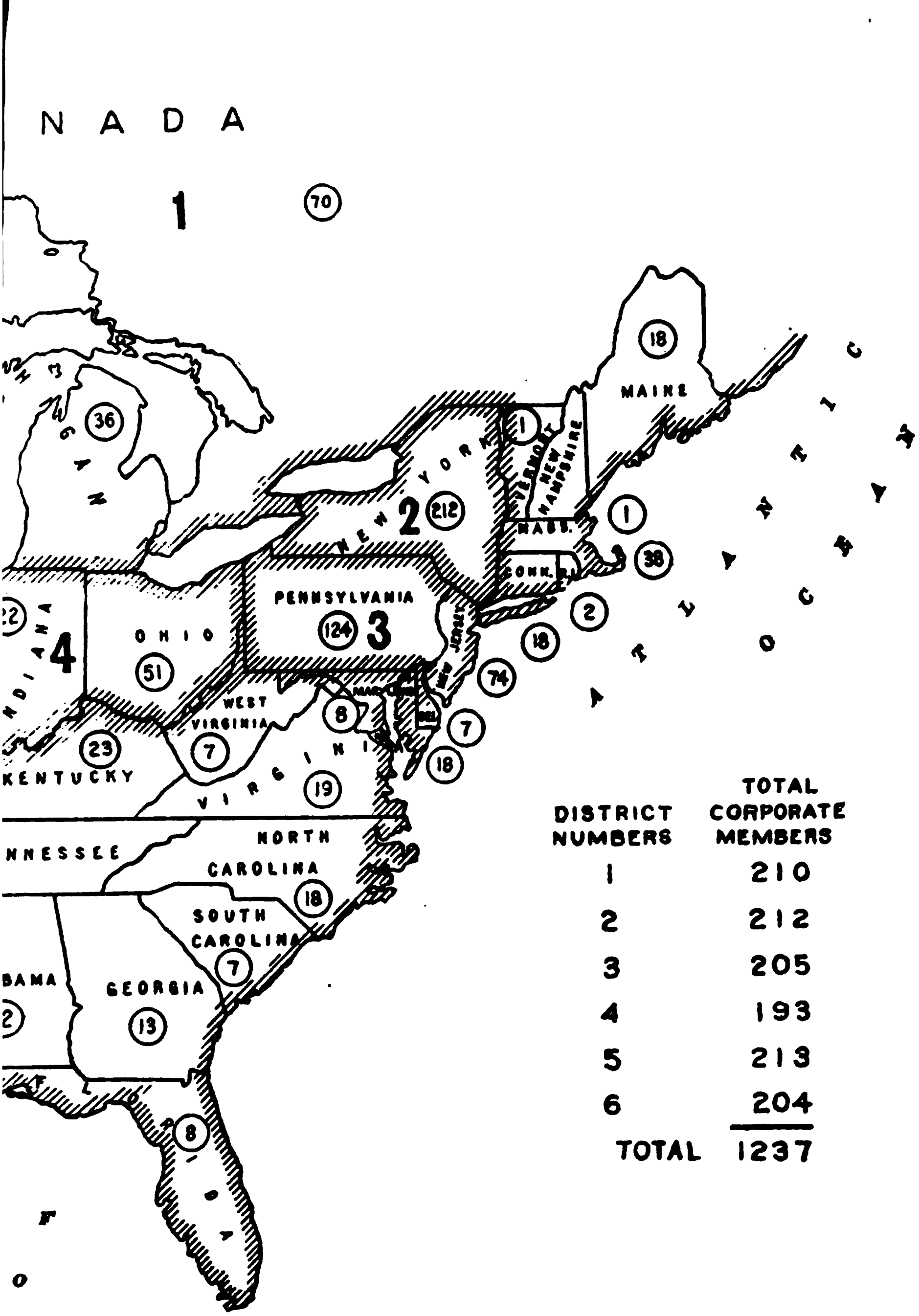
This Nominating Committee, composed of seven members, one being elected from each of the six districts, and the latest living past-President, will meet on or before January 1st for the purpose of selecting nominees for the offices to be filled. Reimbursement for their expenses is provided for. The Committee selects but one nominee for each office to be filled, first obtaining the consent of the nominee to accept nomination and to serve if elected. On or before January 10th the Nominating Committee shall report its list of nominees to the Secretary of the Association, and on or before February 1st the Secretary shall mail to the membership this list of nominees selected by the Committee.

Other nominees may be made by petition before March 1st, and the balloting for officers will follow in the usual manner. Article VI as amended is as follows:

Section 1. The officers of the Association shall be a President, Vice-President, Treasurer, Secretary and Editor of the Association's publications. The offices of the Secretary and Editor may be combined at the discretion of the Executive Committee.

Section 2. There shall be an Executive Committee in which the government of the Association shall be vested. It shall consist of the President, Vice-President, Treasurer, Secretary, Editor, the Chairman of the Finance Committee, the latest two living past-Presidents and six Trustees elected to represent the six districts hereinafter established, one Trustee to be elected from each district to serve three years. The President and Secretary of the Association shall be the President and Secretary of the Executive Committee.

In 1919 one Trustee shall be elected from District 1, and one from District 4, to succeed the present Trustees whose terms expire in 1919; in 1920 one Trustee shall be elected from District 2, and one



DISTRICT NUMBERS	TOTAL CORPORATE MEMBERS
1	210
2	212
3	205
4	193
5	213
6	204
TOTAL	1237

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37)

from District 5 to succeed the present Trustees whose terms expire in 1920; in 1921 one Trustee shall be elected from District 3, and one from District 6, to succeed the present Trustees whose terms expire in 1921; and every year thereafter, two Trustees shall be elected in the districts in which the terms of the incumbents expire.

SECTION 3. The following districts are established for the purpose of territorial representation:

District 1 shall include the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Michigan, Wisconsin and the Dominion of Canada.

District 2 shall include the State of New York.

District 3 shall include the States of New Jersey, Pennsylvania and Delaware.

District 4 shall include the States of Ohio, Indiana and Illinois.

District 5 shall include the District of Columbia and the States of Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Kentucky, Arkansas, Louisiana, Kansas, Oklahoma and Texas.

District 6 shall include all other States and Territories of the Union, and all territory outside of the United States not otherwise provided for.

The boundary lines of these districts may be changed by majority vote of the Association at any time when it becomes necessary so to do in order to preserve approximately the same number of voting members in each district. Should any Trustee be thrown into another district by changes made in the boundary lines, he shall serve out his term of office and be accredited as the representative either of his old district or of the district in which he resides, as the Executive Committee may determine.

SECTION 4. On or before the first day of November of each year, the Executive Committee shall appoint a Nominating Committee composed of seven members, one from each district, together with the latest living past-President of the Association who shall be the Chairman of the Committee. The district members thus appointed shall be those active, honorary or corporate members who receive from their respective districts the largest number of votes of the general membership obtained in the following manner: members from each district present at the Annual Meeting shall submit one name and may submit two, but not more, from members from that district, as candidates for the Nominating Committee for that dis-

trict; the names submitted, together with any others sent to the Secretary within sixty days after the Annual Meeting, over the signatures of at least twenty-five voting members from the district for which the candidate is to be elected, shall be printed on a ballot and mailed to the voting membership of each district not later than the first day of October following, but voting shall not be restricted to such names. The polls shall be closed at the Secretary's office at noon October 20th. The said ballots for each district shall have only the names of the candidates for that district printed thereon with space left for inserting another name by the voter. The method of balloting shall be the same as that provided hereafter for election of officers. Should there be a tie vote in any district, the Executive Committee shall decide by vote which of the candidates receiving the largest number of votes shall be appointed.

On or before the first day of January following, the Nominating Committee so elected shall meet at some convenient point for the purpose of selecting nominees for the offices to be filled. Railroad fares of the members of the Committee attending this meeting, on the basis of an allowance of four cents per mile of travel, shall be paid by the Association after the accounts have been approved by the Chairman of the Nominating Committee and by the Finance Committee. The Nominating Committee shall select only one nominee for each office to be filled, after obtaining the consent of the nominee to accept nomination and to serve if elected.

On or before January 10 the Nominating Committee shall report its list of nominees to the Secretary of the Association, who shall before the first day of February cause to be mailed to the membership the list of nominees selected by the Nominating Committee. At any time prior to noon on the first day of March of each year additional nominations may be made by request to the Secretary, signed by at least twenty-five Active, Honorary or Corporate members, and upon the receipt of such request the Secretary shall, after acceptance of the nomination by the candidate, add such additional nominees to the final ballot to be prepared by him. The nominees of the Nominating Committee shall head such final ballot for each office, and any additional nominees for the respective offices shall be placed under the nominees of the Committee in alphabetical order.

SECTION 5. Election shall be by letter ballot. At least two months before the date of the Annual Meeting, a ticket shall be mailed to each member of the Association entitled to vote. Each

member shall be entitled to vote for one candidate for President, one candidate for Vice-President, one candidate for Treasurer and two candidates for Trustees. The ballot shall be sealed separately in a special ballot envelope. This ballot envelope shall be enclosed in a larger envelope and forwarded to the Secretary. The signature of the member voting shall appear on the outer envelope.

The Secretary with two canvassers appointed by the President shall meet at a time and place directed by the President, and shall open and count all ballots cast by persons entitled to vote. No ballot shall be counted if received later than noon of the seventh day previous to the beginning of the Annual Meeting.

The result of the canvass for President, Vice-President, Treasurer and Trustees shall be declared by the President at the Annual Meeting on certification of the canvassing board. The members who shall have received the highest number of votes cast for the several offices shall be declared elected. If there be a tie vote the President shall order a vote to be taken in the Annual Meeting to decide which person of those who shall have received the same number of ballots shall be chosen.

The terms of the officers so elected shall be as follows: For the President, Vice-President, and Treasurer, each one year beginning with the close of the last day of the Annual Meeting and ending the last day of the next Annual Meeting, or until their successors shall have been chosen; for the Trustees, three years beginning with the close of the last day of the Annual Meeting, or until their successors shall have been chosen.

SECTION 6. Before the close of each Annual Convention, the Executive Committee elected to serve during the year ensuing, shall organize and elect a Secretary and an Editor, to serve until the close of the next Annual Convention, or until their successors are chosen.

SECTION 7. In case of inability of the President to perform the duties of his office, his position shall be temporarily filled by the Vice-President, and in case of inability of the Vice-President, his position shall be filled by one of the Trustees; the order of precedence being governed by priority in date of election as Trustee, or if the dates of election be the same, by priority in date of the admission of such Trustees to membership in the Association.

SECTION 8. All vacancies in office, except as provided in Section 7 hereof, shall be filled by vote of the Executive Committee for the unexpired term of said office as soon as practicable after said vacancy occurs.

SECTION 9. The President, Vice-President and Trustees shall be ineligible to election to the same office for consecutive terms.

AMENDMENT TO ARTICLE VIII

This proposed amendment is in the line of an endeavor to improve the present method of selecting places for holding Annual Conventions. Heretofore much valuable time during the Annual Meetings has been unnecessarily consumed in selecting the next Annual Meeting place. This amendment creates a Convention Committee, to be appointed each year by the incoming Executive Committee. This is to be a committee of three, one of whom is to be the Secretary of the Association. Its duty is to investigate all invitations from cities, and to satisfy itself that proper facilities are available for all purposes of the convention. During each Annual Meeting this committee will hold a meeting at which advocates of the various places extending invitations will be heard. The Convention Committee will report its findings to the Executive Committee, and the Executive Committee to the Convention, and after a place has been selected one or more of the Convention Committee will visit the place selected and ascertain whether the guarantees can be satisfactorily carried out, and if so make the necessary arrangements. Reimbursement for the expenses of the committee is provided for. The proposed amendments to Article VIII follow:

SECTION 1. There shall be four standing Committees, the Finance Committee, the Membership Committee, the Publication Committee and the Convention Committee. The members of each shall be appointed by the incoming Executive Committee. They shall serve for one year beginning with the close of the last day of the Annual Meeting or until their successors shall have been appointed. Special Committees may be appointed at any time by the President.

Add a new section numbered 5 to Article VIII to read as follows:

SECTION 5. The Convention Committee, which shall consist of three members, one of whom shall be the Secretary, shall investigate all invitations to hold conventions of the Association, satisfying itself that the places extending the invitations have proper facilities for the accommodation of the members and guests, for holding the meetings of the Association with its National Sections, and for exhibits by associate members. This Committee shall invite the

Convention Committee of the Water Works Manufacturers' Association to coöperate with it. The Committee shall prepare and send to all cities extending invitations to hold conventions a form containing such questions as may be necessary to properly inform the Committee as to the convention facilities offered. The information shall include a diagram of the rooms offered for meeting rooms, Committee and Section rooms and exhibition space, also a list of available hotels, with guaranteed rates and the number that each will accommodate; points of interest to water works people, and entertainment, if any, offered.

During each Annual Convention the Committee shall hold a meeting, at which advocates of various places extending invitations shall be heard, and at the time designated by the Executive Committee for the selection of the place for holding the next Annual Convention the Committee shall make a report to the convention, stating in alphabetical order the invitations received and fully and impartially set forth the advantages and facilities offered by each. Should no invitations be received it shall be the duty of the Committee to ascertain what arrangements can be made for holding a convention, and to report to the Executive Committee before the convention convenes.

The Committee, or one or more members of the Committee, may, as soon as practicable after the place for holding a convention has been selected, visit such place and ascertain whether the guarantees can be fully carried out, and whether it is a suitable place for holding a convention of the Association; also, if the place is approved, to make the necessary arrangements for holding the convention. If, after such visit, it is the judgment of the Committee that the place is not suitable, or does not offer proper facilities, or for any other reason it would not be for the best interests of the Association to hold its convention there, the Committee shall immediately report its findings to the Executive Committee, with its recommendations as to the meeting place for the next Annual Meeting. The expenses of the Committee or members of the Committee, in making such visits to be borne by the Association, on the basis of an allowance of four cents per mile travel.

AMENDMENTS TO ARTICLE X

This proposed amendment seeks to clarify the somewhat ambig. uous phrasing of the laws governing expenditures by local sections- Its passage is particularly recommended by the Finance Committee

on account of certain misunderstandings which arose last year with respect to the manner in which the expenses of sections should be financed. As amended Section 4 of Article X is as follows:

Section 4. Each Local Section as soon as established, and after its rules have been approved by the Executive Committee, may, with the approval of the Finance Committee, annually receive from the Treasurer of the Association, for local use, not more than twenty-five per cent of the annual dues paid to the Association by the members of the said Local Section; except that in no case shall the total of all moneys received by any Local Section for any one fiscal year exceed the sum of One Hundred and Fifty Dollars; and except that Local Sections with small memberships, where the alloted twenty-five per cent of the annual dues paid to the Association by the members of the said Local Section does not amount to Fifty Dollars, such Local Sections shall be entitled to receive from the Treasurer of the Association, for local use, not more than Fifty Dollars in any one fiscal year.

The Treasurer of each Local Section shall forward to the Secretary of the Association his application endorsed by the presiding officer of the Section for such portions of the said sums above specified as may be needed; and upon receipt of such application the Secretary shall request the Finance Committee to authorize the Treasurer of the Association to pay such sums to the Treasurer of the Local Section. These moneys may be used by the Local Section only in payment of necessary operating expenses incurred by the Section, such as printing, stationery, postage, rent and care of meeting room, light, fuel, stenographer and stereopticon operator services at meetings, etc.

At the end of each fiscal year the Treasurer of each Local Section shall submit a certified copy of his accounts to the Secretary of the Association, the same being itemized and showing the balance on hand of the funds received from the Association. This balance shall be returned to the Secretary of the Association, or shall be charged to the Local Section as a portion of its quota for the following year.

Special Advisory Commission on the Constitution.

George A. Johnson, *Chairman.*
Morris R. Sherrerd,
Carleton E. Davis,
Garrett O. House,
Edward E. Wall.

SOCIETY AFFAIRS

PROCEEDINGS THIRTY-EIGHTH ANNUAL CONVENTION

The Thirty-eighth Annual Convention of the American Water Works Convention was held at the Planters' Hotel, St. Louis, Missouri, May 13–17, 1918, an exhibit by the members of the Water Works Manufacturers' Association being held concurrently at the same hotel. Although the constitution requires the opening session to be held on Tuesday, an informal meeting was held on the evening of Monday, May 13. Water Commissioner Edward E. Wall., of St. Louis, introduced Mayor H. W. Keil, who delivered an address of welcome, which was responded to by Past President Leonard Metcalf. A reception and dance followed, by invitation of the Local Entertainment Committee, of which Commissioner Wall was chairman.

Tuesday Morning, May 14. Major Theodore A. Leisen, Q.M.R.C., President of the Association, being unable on account of official duties to be present at this time, the session was called to order at 9.00 a.m., by the Vice President, Allen W. Cuddeback, who presided during the greater part of the convention.

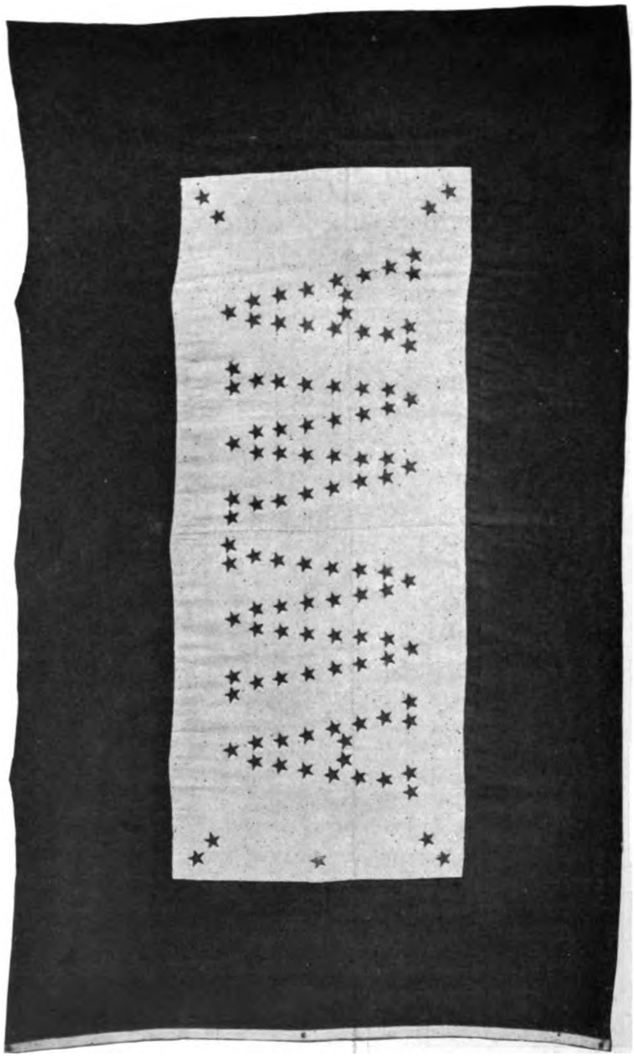
The Canvassing Committee, Jas. H. Caldwell and Wm. P. Mason, reported that the vote on the election of officers was unanimous for the regular nominees. The chair accordingly declared the following were duly elected officers for the ensuing year: President, Charles R. Henderson, Davenport, Iowa; Vice President, Carleton E. Davis, Philadelphia, Pa.; Treasurer, James M. Caird, Troy, N. Y. Trustees, term expiring 1921: Jack J. Hinman, Jr., Iowa City, Ia.; Allen W. Cuddeback, Paterson, N. J.

Geo. A. Johnson, Chairman, read the Report of the Executive Committee, which is printed on page 375.

On motion of Geo. A. Johnson, the Convention tendered to Miss Charlotte S. Edgley a unanimous and rising vote of thanks for presenting to the Association a service flag which was hung in the hotel lobby.

The recommendation of the Executive Committee advising remitting due of members in the military and naval service was discussed by

Messrs. Chester, Wiles, Kemble, Metcalf, Hatton, Cole and Diven. The Association voted to concur in the recommendation. On motion



SERVICE FLAG OF THE AMERICAN WATER WORKS ASSOCIATION

Made and presented to the Association at the convention in St. Louis, May, 1918, by Miss Charlotte S. Edgley, Assistant to the Secretary.

of Henry B. Morgan, it was voted that if any members have been dropped from membership while in the service because of non-payment of dues, such dues should be remitted and these members re-instated.

Geo. W. Fuller delivered an address, illustrated by lantern slides, explanatory of the emergency construction at the various cantonments from the water works standpoint. The address was discussed by Messrs. Metcalf, Little, Werner and Fuller.

On motion of F. C. Jordan, the following resolution was adopted by a unanimous rising vote:

RESOLVED: That Vice President Cuddeback be requested to telegraph to Ex-President Dabney H. Maury our deep sense of his valuable work in furtherance of the prosecution of the war, and our congratulations upon the success of his patriotic and fruitful efforts, and the pledge of the American Water Works Association to coöperate with Lieutenant-Colonel Maury in every way possible to still further develop and carry forward his plans.

The Report of the Special Advisory Committee on Amendments to the Constitution was presented; it is printed on page 355.

After discussion by Messrs. Metcalf, Chester, Wall and Henderson, the entire report of the Committee was concurred in and the several amendments as reported by them and distributed in printed form to the membership, were adopted as read.

Tuesday Night, May 14, 1918. Geo. A. Johnson in pursuance of a vote of the Executive Committee presented the following draft of a letter to Secretary McAdoo for consideration:

St. Louis, Mo., May 14, 1918.

Hon. William G. McAdoo,
Secretary of the Treasury,
Washington, D. C.

DEAR SIR:

The American Water Works Association, in convention assembled, contemplating with alarm the conditions existing with reference to difficulties experienced by its members during the past year in obtaining the materials essential to efficient and economical maintenance of satisfactory water service, is impelled to direct your attention to this extremely important matter and earnestly to express the hope that amelioration steps will be taken immediately that this highly essential branch of public service may not be allowed further to depreciate at the expense of increased public sickness, public discomfort, industrial inconvenience, faltering war activities and fire hazard.

The American Water Works Association is a national organization with about 1300 members, representing every state, 481 towns and cities, 37,000,000 persons in the United States, and water works in 18 foreign countries. It reports through its members—water works superintendents, commissioners, managers, engineers and operators,—increasing difficulties in construction, operation, and maintenance of their water works, and many examples fore-

boding menace to the public health and industrial war activities and of loss by fire due to impaired service.

Our water works superintendents and managers complain of great difficulty in obtaining reasonably prompt deliveries of materials essential to the satisfactory operation and maintenance of the works in their charge; manufacturers and builders of water works of futile results of applications to the Car Service Commission in efforts to obtain the delivery of materials without which the highly needed extensions or repairs to existing water works systems cannot be made. The situation is critical and merits immediate adjustment that the prosecution of the war be not hampered, nor the health and well being of the Nation be threatened, due to faltering or unsatisfactory water service.

To this end we respectfully commend to your favorable action the appended list of materials essential to the satisfactory and economical performance of the water departments of America, and request that they be placed at once on the essential list, and furthermore that they actually be given all reasonable priority in transportation.

Very respectfully,
THE AMERICAN WATER WORKS ASSOCIATION.
By ——————, *President.*

Approved by the Executive Committee
Ratified by the Association in General Convention at St. Louis, Mo., May 14, 1918.

By——————, *Secretary.*

On motion of Walter Edward Miller, seconded by Geo. W. Fuller, the recommendation of the Executive Committee was concurred in and the foregoing draft of letter approved, by unanimous vote.

A discussion on the increased cost of operation of water works and the difficulties under which they are being managed under war conditions, was held, in which Geo. A. Johnson, J. G. Chester, N. T. Veatch, Jr., and Leonard Metcalf participated.

E. R. Conant read a paper on "The Artesian Water Supply of Savannah, Ga.," which was discussed by J. N. Chester and Walter E. Miller.

In the absence of Louis L. Tribus, New York City, his paper on "Water Treatment Conditions at Council Grove, Kans." was read by Geo. A. Johnson, and discussed by C. C. Young.

Wednesday Morning, May 15. The President, Major Theodore A. Leisen, Q.M.R.C., officer in charge of utilities, Camp Custer, Mich., occupied the chair at this session and delivered the Annual Presidential Address, printed on page 250.

The chairman of the Finance Committee, George A. Johnson, presented its report, which is printed on page 376. In addition he gave in

detail the expenditures for the preceding year, so as to furnish the members with a full understanding of the proposed budget for the ensuing year. He further referred to the fact that there was a movement on foot to improve the character of the JOURNAL and allowance had been made for that, to be acted on by the incoming Executive Committee. On motion of J. N. Chester, the report was accepted and filed.

Chairman of Publication Committee presented the report of that Committee which is printed on page 380.

On motion of R. F. Johnson, the report was approved, especially its recommendations in regard to the JOURNAL.

The report of the Committee on Revision of Standard Specifications for Cast Iron Pipe and Specials, John H. Gregory, Chairman, was presented. It was the same report that was submitted at the Richmond Convention in May, 1917, and printed in the JOURNAL for September of that year, but was accompanied by a tentative draft of standard specifications printed on page 385 of this number. The report and specifications were sent to the members with a questionnaire. In reply to these questions, 33 voted in favor of revising the present specifications and 13 against revision or questioned its usefulness, 32 voted for and 12 against a uniform outside diameter, 26 voted for and 11 against specifying chemical requirements, and 29 voted for and 6 against specifying a relation between flexure and the breaking load. The report was discussed by E. E. Wall. H. B. Morgan, Leonard Metcalf, Walter Wood and T. A. Leisen, and at the close of the discussion it was voted to continue the Committee.

The following were selected members of the Nominating Committee from the several districts, viz.:

District 1. H. Hymmen, Kitchener, Ont.

District 2. Harry F. Huy, Buffalo, N. Y.

District 3. Chas. R. Wood, Philadelphia, Pa., and E. W. Humphrey, Erie, Pa.

District 4. Henry B. Morgan, Peoria, Ill., and W. W. DeBerard, Chicago, Ill.

District 5. J. A. Steele, Jr., Vicksburg, Miss.

District 6. John A. Caulfield, Bismarck, N. D.

In the voting for the next convention city, 114 votes were cast for Buffalo, and 52 votes for Detroit, and on motion of Mr. Wall, seconded by Major Leisen, the selection of Buffalo was made unanimous.

Albert P. Greensfelder, President American Society of Engineering Contractors, St. Louis, Mo., presented a paper on "De-Hydrated Contracts." On motion of Mr. Wall, the President was directed to appoint a special committee to draft a standard form of contract and bond, to report at the next convention.

Wednesday night, May 15. Jack J. Hinman, Jr., presented a paper on "Literature of Field Water Supply."

Robert B. Morse, and Abel Wolman presented jointly a paper on "The Practicability of Adopting Standards of Quality for Water Supplies," which was discussed by Jack J. Hinman, Jr., C. Arthur Brown, and W. S. Cramer.

On account of the lateness of the hour a paper on "Preliminary Analysis of the Degree and Nature of Bacterial Removal in Filter Plants," by Abel Wolman, was read by title.

Superintendent's day, Thursday morning, May 16. Vice President Cuddeback read the following telegram from Lieutenant-Colonel Maury:

I am deeply grateful for message of congratulation and pledge of coöperation. The credit for whatever has been accomplished belongs to the entire Construction Division with which I was lucky enough to be associated. Please convey to my friends and fellow-members my most cordial greetings and best wishes for success of convention. Nothing but the work here could prevent my being with you.

DABNEY H. MAURY.

Discussion on experiences with frozen services, mains and meters during the severe winter of 1917–1918 was opened by Vice-President Cuddeback and papers on the same subject were presented from F. E. Kingsbury, A. R. Hathaway, John T. Metcalf, J. M. Diven, Samuel E. Killam, J. Walter Ackerman, William W. Brush, and Charles A. Windholz. In addition there was oral discussion by W. H. Randall, C. W. Wiles, Robert C. Wheeler, Dr. M. P. Conway, Walter Edward Miller, Dow R. Gwinn, H. Hymmen, C. W. Schiedel. James P. Flatlay, F. T. Kemble, L. B. Landmann, Alvin Bugbee, Beekman C. Little, Wm. Luscombe, E. E. Davis, W. H. Randall, W. A. Judd, R. F. Johnson, A. F. Mellen, Wm. H. Henby, J. Arthur Jensen, and Henry P. Bohmann.

Superintendents' day, Thursday afternoon, May 16. Vice-President Cuddeback read a letter from Wm. W. Brush, calling special attention to a questionnaire on frozen services and mains, sent to members of the New York Section, which Mr. Bettes requested to have

laid before the Convention. Mr. Brush stated that the New York Section would not feel hurt if the convention should decide to have a committee appointed representative of all sections to secure the desired information.

Mr. Cuddeback referred to the extensive interest in frozen services and thought the subject could best be handled by a special committee to consider all of the papers presented and the discussions of the morning. On motion of W. H. Randall, the appointment of such a committee was authorized. The question as to whether it is advisable for the Association to adopt a standard form of electrical thawing machine was referred to the special committee just appointed.

Thomas E. Flaherty presented a paper on "Office Records," which was illustrated by lantern slides.

Mr. Cuddeback showed lantern slides illustrating office records and the method of keeping them.

F. M. Griswold addressed the convention, in reference to the national standard thread on all hose couplings and hydrant outlets.

Mr. Cuddeback presented a paper on "Water Consumption," illustrating it with lantern slides.

Office records and consumption were discussed by E. R. Townsend, Chester R. McFarland, and E. E. Davis.

Thursday night, May 16. A. V. Graf read a paper on "Some Aspects of Chemical Treatment at St. Louis Water Works," which was discussed by Dow R. Gwinn.

C. M. Daily read a paper on "The Double Forty-Eight Inch Manifold at Bissell's Point," illustrated by lantern slides. (No discussion.)

L. A. Day read a paper on "The New 110,000,000 Gallon Pump at Chain of Rocks," illustrated by slides. (No discussion.)

Friday morning, May 17. By unanimous vote, and with applause, the following telegram was read and ordered published in the JOURNAL.

France, May 17, 1918.

President American Water Works Association, St. Louis, Mo.

Greetings; Babbitt, Bartow, Bowles, Brennan, Buswell, Catlett, Ferguson, Fritze, Hale, Hadsen, Hawley, Hazlehurst, Lee, Letton, Mitchell, Murphy, Pugh, Roberts, Suter, Scharff, Walker, American Force.

[SIGNED] LONGLEY.

There being no one present representing the Committee on Standard Specifications for Wrought Iron Pipe, the committee was discharged and the President authorized to re-appoint if found advisable all of the members of the present Committee.

Philip Burgess, chairman of Committee on Mechanical Analysis of Sand, sent a letter stating that a progress report had been prepared, which was accompanied by notes by other members of the Committee; and on motion of Dow R. Gwinn this was referred to the Publication Committee. It is printed on page 345.

The Committee on City Planning, presented no report, the Chairman having resigned his membership in this Association. On motion of Mr. Gwinn, the committee was discharged, with thanks.

A letter was read from Nicholas S. Hill, Jr., chairman of the Committee on Private Fire Protection Service, advising that it had proved impossible to do anything during the present year by reason of several members of this committee being actively engaged on government work and unable to look after Association affairs. On motion, the Committee was discharged, and the president authorized to appoint a new Committee to undertake some positive action. A general discussion followed on the subject of private fire protection service, participated in by W. J. Wills, J. M. Diven, W. H. Randall, Dow R. Gwinn, Chester R. McFarland, E. E. Davis, Henry B. Morgan, George C. Habermeyer, E. E. Wall, J. Walter Ackerman, C. W. Schiedel, and A. W. Cuddeback. On motion of Mr. Gwinn, seconded by C. R. McFarland, the following resolution was adopted unanimously:

Resolved: That it is the sense of the American Water Works Association in Thirty-eighth Annual Convention assembled at St. Louis, Mo., May 14–17, 1918, that private fire protection is valuable and should be paid for by those who enjoy this unusual privilege; that the Water Works Department or Company shall in all cases specify the size of the connections to be made with the water mains; that no permit be issued for private fire protection connections without the approval of the Chief of the Fire Department; that all private fire protection lines shall be metered; that all those desiring private fire connections shall submit plans and blue-prints of the proposed lines through their factories or premises, and that no permit shall be issued for connection to the mains until such plans and blue-prints are filed with and duly approved by the Superintendent of the Water Department or Company; that in furnishing private fire protection the Water Department or Company does not guarantee to furnish the proper quantity of water through the fire protection services or to guarantee anything relative to such service; further that there shall be no connection between the fire protection services and any other source of supply.

No report having been received from the Committee on Official Standards of Water Analysis, the question of whether the Committee should be continued was left to the discretion of the President.

The Committee on Classification of Technical Literature was discharged, with thanks for the work it had done.

On motion of C. W. Wiles, the President was authorized to appoint a new Committee on Depreciation, the correspondence now in hand referring to this subject to be turned over to it.

On motion of Water Commissioner Wall, St. Louis, Mo., a unanimous vote of thanks was tendered to the United Railways Company of St. Louis for courtesies received.

On motion of Secretary Diven a rising vote of thanks was tendered to the Local Committees and especially the Ladies' Committees, for the way in which the visiting members and guests were entertained at St. Louis.

W. A. Foley read a paper on "Some Phases of Distribution Work," illustrated by lantern slides. The paper was highly commended by Chairman Cramer, and on motion of W. H. Randall a special vote of thanks was tendered the author.

ILLINOIS SECTION

The tenth annual meeting of the Illinois Section was held at Urbana on April 16 and 17. In welcoming the Section, Vice President David Kinley of the University of Illinois made the significant statement that there were not the same numbers of students to be seen because about 1800 undergraduates had gone into war service. It might be added that of seventeen members residing in Champaign and Urbana five are now army officers and three are working directly for the government. The attendance was 43, small for an annual meeting of this Section and due, according to Chairman E. MacDonald, to the absence in government work or arduous war-time labors of many of the men hitherto prominent in the Section's affairs. The treasurer reported that the Section was without indebtedness.

The papers presented were as follows:

"Unusual Winter Conditions at Evanston," I. C. Brower.

"Homemade Thawing Machine," F. C. Amsbary.

"Water Waste Elimination; Methods and Results at Oak Park," H. P. T. Matte.

"Letters from the Front," W. W. DeBerard.

"Storage of Coal," Prof. H. H. Stoek.

"Reclamation," Prof. F. H. Newell.

"Water Supply and Sanitation at Government Camps," S. A. Greeley.

"Some Tests of Electrically Operated Deep-Well Pumps," P. S. Biegler and I. W. Fisk.

"Some Recent Sewage Treatment Work," W. D. Hatfield.

"The Property of Certain Water, with Reference to their Action on Metals," Prof. S. W. Parr.

"Reinforced Concrete Pressure Pipe," Coleman Meriwether.

"Pollution and Fish Life," Prof. Victor Shelford.

The Secretary, G. C. Habermeyer, reported that the Section had 110 active members, 1 corporate member and 14 associate members on April 16, 1918.

In the election of officers W. W. DeBerard was chosen chairman, W. E. Lautz vice-chairman, H. E. Keeler treasurer, and F. C. Amsbary trustee. H. M. Ely was elected trustee to fill the unexpired term of Mr. Lautz.

During the meeting the annual dinner was served at Hotel Beardsley, the University student brigade was reviewed, and a visit paid to Chanute Field aviation school.

The following resolution was adopted:

Whereas, Circular No. C. S. 1-A, issued March 26, 1918, by the United States Railroad Administration states that liquid chlorine, alum, sulphate of iron and similar chemicals are exempt from embargo when to be used for purification of public water supplies and consigned to municipal authorities, and

Whereas, it is apprehended that some local railroad officials may interpret the wording "municipal authorities" too strictly in case of private ownership of plants, and

Whereas, other materials in addition to chemicals are just as essential to the proper protection of the health and property of the community, Therefore be it

Resolved, that the Illinois Section of the American Water Works Association recommend to the American Water Works Association that it take up the matter of relief in shipments of materials for the maintenance and operation of public water supplies by requesting United States Railroad Administration, Division of Transportation, Car Service Section, for priority of such materials and supplies.

OBITUARY NOTICES

B. F. Souder, Superintendent of Distribution, Atlantic City, N. J.; elected June 24, 1913; died May 23, 1918.

William R. Hill, Consulting Engineer, Albany, N. Y.; elected member, June 9, 1897; died June 16, 1918.

TREASURER'S REPORT

Troy, N. Y., March 31, 1918.

Permit me to submit my report as Treasurer of The American Water Works Association for the year ending March 31, 1918.

The funds of the Association are on deposit with The Troy Trust Company, Troy, N. Y.

The receipts during the year were as follows:

Balance April 1, 1917	$3,262.36
Received from J. M. Diven, Secretary	10,568.01
Interest on deposits	118.92
Interest on investments	335.00
Total	$14,284.29
Disbursements as per vouchers, cancelled checks and debit slips	$12,796.59
Balance, April 1, 1918	$1,487.70

The disbursements include $5,000.00 used for the purchase of United States Liberty Bonds for the Permanent Fund.

Attached you will find certificate of The Troy Trust Company showing a deposit of $1,511.80 at the close of business March 30, 1918.

From this balance there should be deducted the following for unreturned checks.

Deposit as per certificate		$1,511.80
Unreturned checks		
V785—Ck. 955 A. C. Schmidt	11.50	
793—Ck. 963 Nora Pederson	3.00	
794—Ck. 964 H. A. Whittaker	5.85	
795—Ck. 965 Williams & Wilkins Co	3.75	$24.10
Balance, April 1, 1918		$1,487.70

The receipted vouchers, cancelled checks and debit slips with the book of the Treasurer are submitted for audit.

The Permanent Fund now consists of the following:

4-$1,000. Dominion of Canada 15 yr. 5% Bonds. (no. 23795-24460-24693-24694)	$4,000.00
2-$1,000. Am. Foreign Sec. Co. 3 yr. 5% Notes. (M-31719-M31720)	$2,000.00
4-$500. U. S. Liberty Loan of 1917 3-½% Bonds. (113880-113881-113882-113883)	$2,000.00

1-$1,000.	U. S. Liberty Loan of 1917 4% Bond. (114824)...	$1,000.00
1-$2,000.	U. S. Certificate of Indebtedness 4-½%.........	$2,000.00
Par value of permanent fund............................		$11,000.00

The Treasurer receives no salary and is under bond as per the order of your Committee.

James M. Caird,
Treasurer.

The Troy Trust Company

Troy, N. Y., March 30, 1918.

This is to certify that at the close of business March 30th, 1918, the balance to the credit of the American Water Works Association was Fifteen Hundred Eleven and 80/100 Dollars ($1,511.80).

Harold K. Downing,
Vice-President.

REPORTS OF COMMITTEES

REPORT OF EXECUTIVE COMMITTEE

The present Executive Committee met for organization following the announcement of the election of officers at the convention at Richmond last May, and elected John M. Diven, secretary, John M. Goodell, editor, and George A. Johnson, chairman of the Finance Committee.

A meeting of the Executive Committee was held at the Hotel Astor, New York City, on December 1, 1917, at which the chairman of the Constitutional Revision Committee reported. All members of the Executive Committee, with the exception of Mr. Rust, were present. The proposed revision of the Constitution was thoroughly discussed, and a final revision was agreed upon for submission to this convention.

At the request of the American Society of Mechanical Engineers, Nicholas S. Hill, Jr., with John N. Chester as alternate, was appointed as a representative to attend the public hearing on the Power Test Codes of that Society held in New York City, December 7, 1917.

The honor roll was brought up for discussion, and it was decided to include in this roll not only the members but also the sons and daughters in service, and to print the honor roll in the JOURNAL, and to display in a conspicuous place at the convention a service flag. Mr. Diven announced that Miss Edgley, his assistant, desired to furnish a service flag for the Association. The Executive Committee accepted the offer with gratitude, and now suggests that a vote of thanks by the convention for this very much appreciated service to the Association would be appropriate.

The following resolution was adopted:

RESOLVED: That the Executive Committee recommends to the Association that the dues of all members entering the service of the Army or Navy of the United States, or its Allies, be remitted during the period of the war.

Mr. Kienle appeared before the Executive Committee to ask for a definition of its policy with regard to the giving of badges to

associate members who are not members of the Manufacturers' Association, and to guests. The Executive Committee informed him that it could not discriminate between associate members who were and who were not members of the Manufacturers' Association, and that the associate members' badge must be given to all associate members on application, regardless of the Manufacturers' Association; that the Manufacturers' Association might if it so wished add to the regular badge of associate members some distinctive mark which would indicate that an associate member was also a member of the Manufacturers' Association; that while the Executive Committee believed it advantageous generally for associate members to become members also of the Manufacturers' Association, it could take no action directed to forcing associate members to become also members of the Manufacturers' Association; that in view of the growth in importance of the convention to the technical press, as indicated by the increased number of its representatives present at the convention, it was of the opinion that it would be desirable for the various publications having representatives in the Association to become associate members; but that the standing of the representatives of the press who were already or who might become active members of the Association would be in no wise affected by this action, and that it was clearly the sense of the Executive Committee that the guest privilege should not be asked for the additional representatives of associate members wishing to attend the convention with commercial ends in view.

ALLAN W. CUDDEBACK,
Chairman.

REPORT OF THE FINANCE COMMITTEE FOR THE YEAR ENDING MARCH 31, 1918

The Finance Committee present the following report on the financial operations of the Association for the year ending March 31, 1918:

We have audited the books of the secretary and treasurer and found them correct. We have examined and verified all vouchers. Details of the financial operations of the Association, and the various funds and accounts, are fully set forth in the respective reports of the secretary and treasurer, and are in accord with their books. Following is a summarized statement of the past year's accounts:

Summarized statement of accounts for the fiscal year ending March 31, 1918

Balance on hand in bank on April 1, 1917	$3,262.36	
Received from the Secretary	10,568.01	
Interest on deposits	118.92	
Interest on investments	335.00	
Total		$14,284.29
There has been disbursed and paid by the Treasurer on vouchers duly authorized and audited by the Finance Committee for the general operations of the Association	$7,796.59	
There was added to the permanent Investment fund	$5,000.00	
Total		$12,796.59
Leaving on April 1, 1918 a balance in bank to the credit to the Association of		$1,487.70

PERMANENT INVESTMENT FUND

There are now in the hands of the Treasurer, in accordance with the authority granted the Finance Committee by the Executive Committee, securities constituting the Permanent Investment Fund of the Association, as follows:

Four $1000 Dominion of Canada 5% bonds, due April 1, 1931	$4,000.00
Two $1000 American Foreign Security Company 5% notes due August 1, 1919	2,000.00
Four $500 United States First Liberty Loan Bonds, 3½%.	2,000.00
One $1000 United States Second Liberty Loan Bond, 4%.	1,000.00
One $2000 United States Certificate of Indebtedness, 4½%	2,000.00
Par value of Permanent Investment Fund	$11,000.00

On April 1, 1917, there was a balance of $3,262.36 cash in bank. As against this the former Finance Committee had subscribed to the first issue of Liberty Loan Bonds in the amount of $2,000. These were taken up and paid for during the past fiscal year as noted above, and other additions, totalling $3000, were made to the permanent investment fund. At the beginning of the past fiscal year the par value of the permanent investment fund was $6,000. At present it is $11,000.

BUDGET ALLOWANCES AND DISBURSEMENTS

The budget allowance voted by the Executive Committee for the past fiscal year amounted to a total of $11,175.

That the expenditures against no item in the budget for 1917–18 exceeded the allowance is a cause for some gratification. In detail it may be recorded that the convention expenses at Richmond were moderately low. Office expenses for the year were kept well within the allowance. Election expenses were approximately equal to the allowance.

Disbursements for committee expenses amounted to but 32 per cent of the allowance. The expenses of the Executive Committee, amounting to a total of $380.44, and occasioned by a meeting held in New York on December 1, 1917, were borne by the committee, each member paying his pro rata share.

Disbursements for section expenses were well within the allowance. The salaries of the secretary and editor are fixed by the Executive Committee, and the disbursements and allowances consequently balance.

The allowance for printing the JOURNAL was made somewhat more liberal last year in anticipation of increased postal rates and printing charges. These increases did not materialize, and the expenditures against this item amounted to but 60 per cent of the allowance. Expenditures under the contingencies item were restricted to efforts to increase the membership.

Respecting the budget for the fiscal year 1918–1919, the recommended allowances are made on the assumption that the proposed constitutional amendments will be ratified at the St. Louis meeting.

Recommended budget for the year 1918–1919

Convention expenses	$700.00
Office expenses	700.00
Election expenses	200.00
Committee expenses	1,000.00
Section expenses	600.00
Insurance	75.00
Salary of Secretary	1,500.00
Salary of Editor	800.00
Extraordinary expenses of the secretary, treasurer and editor	425.00
Printing and distributing JOURNAL	5,500.00
Total	$11,500.00

Respecting the suggested budget we have the following comments to make:

The allowance for election expenses has been made somewhat larger than last year in order to meet the added expense anticipated by the new procedure in electing officers, necessitating considerable additional printing and postage.

On the assumption that the constitutional amendments are ratified at the St. Louis meeting, members of the Nominating and Convention Committees are to be reimbursed for travelling expenses. In the suggested budget we have estimated such expenses of the Nominating Committee meeting at $280, and those of the Convention Committee at $120. The balance of the allowance for Committee expenses, amounting to $600, should be sufficient to defray the cost incurred for stenographic services, printing and postage by all other committees, including the Additional Membership Committee and Committee on Superintendents Convention Expenses, if such committees are appointed. We believe an allowance of $250 ample for the expenses of the former, and $100 for those of the latter.

In lieu of increasing the salaries of the secretary and editor, it has seemed to us wiser to provide a new item in the budget to take care of extraordinary expenses of these officers who at present pay their own expenses when attending the annual conventions and other committee meetings where their presence is requested. The salaries paid the secretary and editor are not much more than enough to defray the cost of such assistance as they require in the performance of their duties, and it would seem only fair that the Association should make suitable provision for their expenses incurred in attending annual and called meetings, and at times when they are obliged to engage the services of additional stenographic assistance, that they may not be required actually to contribute more than their own time while serving the Association. Accordingly we have introduced an item in the budget under the head of Extraordinary Expenses of the Secretary, Treasurer and Editor to cover these expenses, and hope that our action will be approved.

In the work of our committee during the past year we have carried all accounts on budget depletion sheets, and have found it very helpful to thus have constantly before us a convenient and accurate statement of drafts against and credit balance in each item.

The operations for the past three years have shown an average surplus of nearly $3,000. A well organized plan of campaign for new members would, we believe, result in positive assurance that this annual surplus will be not only maintained but increased materially.

A better journal, that is, one containing a selection of high grade papers covering a wide variety of subjects, such as can well be obtained through judicious soliciting by the Publication Committee, will increase the revenue from subscriptions and advertisements. These are important items, and it must not be forgotten that a high grade journal will not only hold existing members but serve a material purpose in any campaign for getting new members.

The treasurer is now under bond for $10,000, as per order of the Executive Committee.

In conclusion we desire to express our appreciation of the hearty coöperation we have received from the secretary and treasurer, and other officials of the Association, and to state our gratification over the harmonious manner in which it has thus been made possible for us to perform our duties.

George A. Johnson, *Chairman.*
J. Waldo Smith,
Frank A. Barbour.
Finance Committee.

REPORT OF THE PUBLICATION COMMITTEE FOR THE YEAR ENDING MARCH 31, 1918

The Publication Committee was not organized until late in the year, but since then has been giving much thought to the Journal. As a result of its deliberations, the Committee recommends to its successor a more active endeavor to increase the value of the Journal to our members and to all interested in water supply. This quarterly publication is the sole direct return many of our members receive from their dues, and the Publication Committee should make every practicable effort to have this return as large and useful as the funds at its disposal permit. The present Committee believes that material improvements can be made with very little additional expense, provided the members of the Association will coöperate. This is particularly important because, by a modification of some of our existing methods of conducting our meetings, the usefulness of our papers to our members can be materially increased, sectional meetings can be broadened, and our printed records made more representative of the thought of our entire Association.

The present Committee feels very strongly the importance of this subject, because it is so closely related to the purpose of the

Association to be American in fact as well as in name. In these grim days of lofty purpose and most earnest endeavor, when America is giving her all in a cause for which the only possible result of complete success is freedom for all nations, great and small, from the domination of a military autocracy, we must leave untried no means of improving the service we can render the communities we serve. Without the adequate supply of wholesome water which it is our business, our duty, to furnish, all our industry would falter and the prosecution of the war would suffer. We are soldiers who serve at home, and we must serve the best we can in this way.

The best service is only practicable when those striving to render it have at their disposal the experience and opinions of all similarly engaged. The JOURNAL of the American Water Works Association ought to furnish that information. It is not doing so now to the extent it should, and your Committee believes the material improvement of the JOURNAL is one of the duties of the incoming officers which should receive careful attention.

It is quite commonly said that water works construction and management have become so standardized that nothing new, nothing really helpful in a broad sense, is practicable. Your Committee dissents strongly from such a view. Whether a water department is bubbling with vitality or stagnant with mere routine depends largely on the enthusiasm of those at its head. Standardization is a valuable feature of administrative organization, but standardization for all time, never changing routine, is a sure indication of senility. "Only the minds of fools stand still." What we have to do as an Association is to keep our individual members animated with the knowledge of all the progress in our field, and those who say there is no progress worth mentioning in our field, asperse the thousands of men earnestly striving to serve our communities more efficiently, more economically and more intensively.

Unfortunately a considerable part of the progress of our industry is essentially and necessarily slow. Somebody takes a step forward here, another there, a third yonder, and so on until the knowledge of these little advances becomes generally distributed, and we wake up to the fact that the advance has been substantial. For instance, take the progress in sanitary drinking fountains. A few years ago attention was called to the probability that some of these fountains were sanitary only in name. Tests of them were made in

a few places, but it was not until a committee of our Iowa section started an investigation of the subject that sanitarians and water works superintendents realized to any extent that there are "sanitary" drinking fountains which are a distinct menace to health, comparable as such with the public drinking cup. The report of the special committee on sanitary drinking fountains of the Iowa Section will be printed next month in the JOURNAL, and may be taken as a good example of the kind of work which shows that water works administration is not to be classed with driving the cows to pasture but calls for wide knowledge, good judgment and "pep."

The present Publication Committee is convinced that much more work like that of the committee just mentioned should be done. It therefore requests this convention to authorize the President to appoint from time to time such special committees to report on features of water works practice as the president and Publication Committee deem desirable, these committees to report to the Publication Committee. If the reports are considered by the Publication Committee to be in form for discussing, copies should be sent to the secretary of each section, if received early in the Association's year, so that they may be discussed by each section. If received late in the year they can be presented at the annual convention.

This recommendation is made for two reasons. First, it will enable the Publication Committee to start committee work promptly when it is desirable to place the results of that work before the members as quickly as possible. Second, it will enable the Publication Committee to be of greater service to the Sections by aiding them in securing reports on timely topics for their meetings. It will tend to increase the interest in the Sections, to animate the Association and thus increase its membership. The success of the work will depend on the members of these special committees, but it is believed they will not fail, for the topics will be live issues and not pedantic platitudes, such as have killed so many of our committees in the past.

The present Publication Committee also strongly advises its immediate successor to secure papers from individuals known to have made investigations or had experiences of interest to water works officials. The essential purpose of this Association is to help the American people secure wholesome water at the lowest

cost. This calls for engineering, chemical and bacterial knowledge, skill in construction and administrative ability. There are various associations and publications supplying a record of progress in some parts of this list, but there is no organization and no publication, even our own, that has the firm grip on the water works field of activity which is desirable from the viewpoint of good municipal administration. Our JOURNAL must be strengthened by becoming a record of live things, a record of what we are striving for as well as what we have done, before it will itself become really alive. And the only way for it to become alive is to secure the coöperation of those men whose work is resulting in progress. By this we do not mean merely progress in great problems, but progress in the minor but often very perplexing smaller tasks of the water works official.

By requesting papers from individuals able to make useful contributions to the JOURNAL, and by securing the assistance of committees where it is necessary to make comprehensive investigations of a subject, it will be practicable to serve the members better than by following the old publication policy of printing only papers originating in the annual convention or the meetings of the sections. The last Publication Committee considered these methods of improving the JOURNAL, but hesitated about adopting them on account of the possibility of overstraining the financial budget of the Committee through an excessive amount of material for publication. It was justified in this fear by the needlessly long and detailed character of part of the material submitted for publication. The present Publication Committee does not have the same fear, because it believes that the time has come for materially condensing some of the papers it receives. It is not the quantity but the quality of the information in the JOURNAL that will make it most interesting and most useful. Papers that are interesting locally may have only parts of general interest, and the Publication Committee believes that those parts of local interest can be omitted without material loss. This pruning may cause some members to feel injured, to think that it is not worth while writing papers if they are to be cut up and boiled down. Yet this must be done, not only to make the JOURNAL more widely interesting but also to save the time of members who wish to read everything about real progress in water works affairs but wish to be saved the task of picking the wheat of utility from the chaff of merely local interest.

If we can make the JOURNAL more useful, more authoritative. more comprehensive in scope, more alive, we can secure more members and, with greater membership, wield more influence for those improvements needed to give our people all the good water they need.

GEORGE A. JOHNSON, *Chairman.*
WM. W. BRUSH,
H. W. CUDDEBACK,
JAMES W. ARMSTRONG,
JOHN M. GOODELL, *Editor.*
Publication Committee.

TENTATIVE DRAFT OF PROPOSED STANDARD SPECIFICATIONS FOR CAST IRON PIPE AND FITTINGS[1]

DESCRIPTION OF PIPE

SECTION 1. The pipes shall be made with *bell* and spigot *ends or with flange ends* and shall *conform accurately* to the dimensions given in Tables Nos........ and .... They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter.

Bell and spigot pipes shall be at least 12 feet in laying length, exclusive of the bell, and flange pipes shall be at least 12 feet in length face to face of flanges.

All classes of pipe of each size shall have the same outside diameter. All pipes having the same outside diameter shall have the same inside diameter at both ends.

The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 inches from each end of the pipe barrel, so as to obtain the required standard thickness and weight for each size and class of pipe.

DESCRIPTION OF FITTINGS

SECTION 2. *There shall be two types of standard fittings, known as "Bell Fittings" and "Flange Fittings." Fittings having bell or spigot ends, or both, but no flange end or ends, shall be known as "Bell Fittings." Fittings having one or more flange ends shall be known as "Flange Fittings."*

All fittings shall be made in accordance with the cuts and dimensions given in the tables forming a part of these specifications. They shall be true circles in section with their inner and outer surfaces concentric

[1] Submitted to the St. Louis convention May 15, 1918.

Changes from present New England and American specifications are in italics.

on both run and outlet, except where intersections prevent. On all fittings the outside diameter of the barrel on each outlet shall be the same as the outside diameter of the pipe of corresponding size.

For pipes from 4 to 20 inches in diameter, inclusive, one class of fittings known as Class D fittings shall be furnished for all classes of pipe. For pipes over 20 inches in diameter, two classes of fittings, known respectively as Class AB and CD fittings, shall be furnished, Class AB fittings for Class A and Class B pipes, and Class CD fittings or Class C and Class D pipes.

Any fitting not shown in the tables hereto attached shall be known as a "Special Fitting."

VARIATION IN DIAMETER OF BELLS AND SPIGOTS

SECTION 3. Especial care shall be taken to have the *bells* and spigots of the required size. The *bells* and spigots will be tested by circular gages, and no pipe or *fitting* will be accepted *which, for any cause, does not comply with the specified joint space, except as hereinafter allowed.*

The inside diameters of the bells and the outside diameters of the spigot ends of pipes shall not vary from the standard dimensions by more than 0.06 inch for pipes 16 inches or less in diameter; 0.08 inch for pipes 18, 20 and 24 inches in diameter; 0.10 inch for pipes 30, 36 and 42 inches in diameter; 0.13 inch for pipes 48, 54 and 60 inches in diameter; *and 0.18 inch for pipes 72 and 84 inches in diameter.*

The inside diameters of the bells and the outside diameters of the spigot ends of the fittings shall not vary from the standard dimensions by more than 0.08 inch for fittings 16 inches or less in diameter; 0.10 inch for 18-, 20-, and 24-inch fittings; 0.13 inch for 30-, 36-, and 42-inch fittings; 0.16 inch for 48-, 54- and 60-inch fittings; and 0.20 inch for 72- and 84- inch fittings.

VARIATION IN THICKNESS

SECTION 4. For pipes whose standard thickness is less than 1 inch the thickness of metal in the body of the pipe *shall not vary more than 0.08 inch* from the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variation shall not exceed 0.10 inch., except that for spaces *the length across which in*

any direction does not exceed 8 inches, a decreased thickness not exceeding 0.02 inch will be permitted, and for spaces the length across which does not exceed 16 inches in any direction, an increased thickness not exceeding 0.05 inch will be permitted—both in excess of the allowances above stated.

For fittings, a variation 50 per cent greater than that allowed for pipes shall be permitted.

ALLOWABLE PERCENTAGE OF VARIATION IN WEIGHT

SECTION 5. No pipe shall be accepted, the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 inches or less in diameter and 4 per cent, for pipes more than 16 inches in diameter, and no excess above the standard weight of more than the above given percentages for the several sizes shall be paid for. The total weight of pipe to be paid for shall not exceed, for each size and class of pipe received, the sum of the standard weights of the same number of pieces of the given sizes and classes by more than 2 per cent.

No *fitting* shall be accepted, the weight of which shall be less than the standard by more than 10 per cent for *fittings* 12 inches or less in diameter and 8 per cent for larger sizes (except that curves and Y-branches may be 12 per cent below the standard weight); no excess above the standard weight of more than the above given percentages for the several sizes shall be paid for. *The total weight of fittings to be paid for shall not exceed the sum of the standard weights of the same number of pieces of the given sizes and classes by more than 5 per cent.*

QUALITY OF IRON

SECTION 6. All pipes and fittings shall be made of cast iron of good quality and of such character as shall make the metal of the casting strong, tough, and of even grain, and soft enough satisfactorily to admit of drilling and cutting. The metal shall be made without *the admixture of any inferior material,* and shall be remelted in cupola or air furnace.

The contractor shall furnish the engineer with copies of the mill analyses of each heat or run of metal, and shall furnish samples to the engineer for check analyses when required.

The metal for the pipes and fittings shall fulfil the following chemical requirements: Total carbon, 3 to 3.75 per cent; combined carbon, 0.5 to 0.75; silicon, 1.6 to 2; manganese, 0.35 to 0.55; phosphorus, not to exceed 0.90; sulphur, not to exceed 0.10 per cent.

TESTS OF MATERIAL

SECTION 7. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and one inch thick, shall be made, without charge, as often as the engineer may direct, and in default of definite instructions the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall support a load of 2000 pounds, and show a deflection of not less than *0.32 inch before breaking, and an increase in deflection of not less than 0.03 inch for each 200 pounds of ultimate breaking load in excess of 2000 pounds.*

The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

CASTING OF PIPE

SECTION 8. The pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter *may* be cast with the *bell* end up or down, unless *otherwise* specified *by the purchaser*. Pipes 18 inches or more in diameter shall be cast with the bell end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent contraction by subsequent exposure.

QUALITY OF CASTINGS

SECTION 9. The pipes and fittings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which, in the opinion of the engineer, unfit them for the use for which they are intended. No plugging or filling will be allowed.

MARKING

SECTION 10. *Each* pipe and *fitting* shall have distinctly cast upon it the initials of the maker's name, a *letter designating the class to which the casting belongs, and figures showing the year in which it was cast. When cast to order, if required by the purchaser, each pipe and fitting 6 inches or more in diameter shall also have cast upon it a serial number, designating the order in point of time in which it was cast, the serial number to be placed below the date, thus:*

1916	1916	1916
1	2	3

etc., and any initials, not exceeding four, *or a symbol,* which may be required.

The letters and figures shall be cast on the outside, and shall *be not* less than 2 inches in length and $\frac{1}{8}$ inch in relief for pipes *and fittings 10 inches* in diameter and larger. For smaller sizes of pipe, the letters may be 1 inch in length. The weight, *serial number,* and class letter shall be conspicuously painted in white on the inside of each pipe and *fitting* after the coating has become hard.

DEFECTIVE SPIGOT ENDS MAY BE CUT

SECTION 11. Defective spigot ends on pipes 12 inches or more in diameter may be cut off in a lathe, and half-round wrought-iron or *mild-steel* band, shrunk into a groove, cut at the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 feet in length, exclusive of socket.

Pipes may be cast with shrink-head above spigot bead, and such pipe shall not be considered as cut pipe in determining the percentage above referred to.

In case the length of pipe differs from 12 feet, the standard weight of the pipe given in Table shall be modified in accordance therewith.

FLANGES

SECTION 12. *Flanges shall be cast solid and shall be accurately faced smooth and true. Holes for bolts or studs shall be drilled, and the flanges shall be tapered where required. The contractor shall furnish and deliver all bolts and nuts for bolting on manhole covers. The*

bolts and nuts shall be of the best-quality wrought iron or mild steel, with good, sound, well-fitting threads, the nuts to be cold punched. The heads and nuts shall be hexagonal and shall be trimmed and chamfered. The heads, nuts and threads shall be of the United States Standard sizes.

CLEANING AND INSPECTION

SECTION 13. All pipes and *fittings* shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the *engineer* immediately before being *coated.*

COATING

SECTION 14. Every pipe and *fitting* shall be coated inside and out with coal-tar pitch varnish. *Each pipe and fitting shall be heated to a uniform temperature of 320° F., in a suitable oven, before it is dipped, and the material in the tank shall also be maintained at this temperature, and each pipe and fitting shall be kept in the bath for at least five minutes, during which time the temperature of all parts of the bath, including the bottom, shall be as specified.*

After removing the pipe from the bath, it shall be suspended or set in a vertical position until the coating has solidified.

The coating shall be of pitch, made from coal tar, distilled until the naphtha is removed, and sufficient oil to make a smooth coating, tough, elastic, strongly adhesive to the metal, tough and tenacious when cold, and not brittle nor with any tendency to scale off. Coating shall not be soft enough to flow when exposed to summer heat, nor brittle enough to crack and scale when exposed to a temperature below freezing.

The pitch shall be straight-run, coal-tar pitch, which shall soften at 60°F. and melt at 100°F., being a grade in which distillate oils, distilled therefrom, shall have a specific gravity of 1.05. The pitch shall not contain less than 10 per cent nor more than 18 per cent of free carbon.

Fresh pitch and oil shall be added to the tank when necessary to keep the mixture of the proper consistency. The oil used for this purpose shall consist of heavy, coal-tar oil, with a specific gravity of not less than 1.04 at 60°F., and which shall not lose more than 5 per cent of oil when distilled up to 400°F.; not more than 40 per cent of oil when

distilled up to 450°F. If the material in the tank thickens or deteriorates when used, the tank shall be emptied of its contents and refilled with fresh material when deemed necessary by the engineer.

Fittings which are too large to be immersed shall be coated with hot varnish by hand, the fittings to be heated as specified above and the coating applied immediately thereafter.

Faces of flanges and finished surfaces shall be coated with a mixture of grease and white lead immediately after they have been faced and drilled.

Any pipe or *fitting* that is to be recoated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST

SECTION 15. When the coating has become hard, the pipe shall be subjected to a proof by hydrostatic pressure, and if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressures to which the different sizes and classes of pipe shall be subjected are as follows:

CLASS	HYDROSTATIC PRESSURE POUNDS PER SQUARE INCH	
	Diameter less than 20 inches	Diameter 20 inches and ver
A.	300	150
B.	300	200
C.	300	250
D.	300	300

The full hydrostatic pressure shall be applied to the pipes for one minute on pipes 12 inches and less diameter; for two minutes on 14-, 16-, 18-, 20- and 24-inch pipes; for three minutes on 36-inch pipes; and for five minutes on pipes larger than 36 inches in diameter.

Fittings shall also be subjected to a proof by hydrostatic pressure, provided the same is specified in the contract. If tested, the hydrostatic pressures to which the fittings shall be subjected shall be the same as those to which pipes of the same size and class would be subjected and shall be applied for the same length of time.

WEIGHING

Section 16. The pipes and *fittings* shall be weighed for payment under the supervision of the engineer after *they have been coated.* If desired by the purchaser, the pipes and *fittings* shall be weighed after their delivery. The weight so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weigh master. *The cost of weighing after delivery shall be borne by the purchaser.*

Bids shall be submitted and final settlement made upon the basis of a ton of 2000 pounds.

CONTRACTOR TO FURNISH MEN AND MATERIAL

Section 17. The *contractor* shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipes and *fittings,* and should the purchaser have no inspector at the *foundry,* the contractor shall, if required by the purchaser, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of *the chemical and physical tests.*

POWER TO INSPECT

Section 18. The engineer shall be at liberty at all times to inspect the material at the foundry and the molding, casting and coating of the pipes and *fittings.* The forms, sizes, uniformity and conditions of all pipes and *fittings* herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipe or *fitting* which is not in conformity with the specifications or drawings furnished.

INSPECTOR TO REPORT

Section 19. The inspector at the foundry shall report daily to the contractor all pipes and *fittings rejected,* with the causes for rejection.

CASTINGS TO BE DELIVERED SOUND AND PERFECT

Section 20. All pipes and *fittings shall* be delivered in all respects sound and conformable to these specifications. The inspection shall

not relieve the contractor of any of his obligations in this respect, and defective pipes or *fittings* which may have passed the engineer at the foundry or elsewhere shall be at all times liable to rejection, when discovered, until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or *fittings* found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes *and fittings* not to injure the coating, and no pipes, *fittings* or other material of any kind shall be placed in the pipes or *fittings* during transportation *or at* any time after they have *been coated.*

The contractor shall not be held responsible for any expenses or damages incurred in handling or using the castings after they have been accepted at the agreed point of delivery. Any pipe or fitting that proves defective shall, when requested, be replaced by the contractor, the measure of the damage not to exceed the value of the casting found defective. The contractor shall have the right to call for the defective casting to be returned to him at the agreed point of delivery before any allowance for the same is demanded.

DEFINITION OF THE WORD "ENGINEER"

SECTION 21. Wherever the word "engineer" is used herein, it shall be understood to mean the engineer or inspector acting for the purchaser, and his properly authorized agents, limited by the particular duties intrusted to them.

SUPPLEMENT

TO

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 5 SEPTEMBER, 1918 NO. 3

CONSTITUTION

LIST OF PAST PRESIDENTS

LIST OF OFFICERS 1918–1919

LIST OF COMMITTEES 1918–1919

ROLL OF HONOR

LIST OF MEMBERS

IMPORTANT

Kindly notify the secretary promptly of any change in address

J. M. DIVEN, Secretary
47 State St., Troy, N. Y.

CONTENTS

CONSTITUTION OF THE AMERICAN WATER WORKS ASSOCIATION

Adopted June 12, 1913
Amended May 12, 1914
Amended May 12, 1915
Amended May 17, 1918

ARTICLE I

Name

The name of this Association, a corporation organized under the laws of the State of Illinois, shall be "The American Water Works Association."

ARTICLE II

Object

The object of this Association shall be the advancement of knowledge of the design, construction, operation and management of water works, and the encouragement, by social intercourse among its members, of a friendly exchange of information and experience.

ARTICLE III

Membership

SECTION 1. Members of this Association may be either Honorary Members, Active Members, Corporate Members, or Associate Members.

SECTION 2. An Honorary Member shall be one whose scientific or practical knowledge in matters related to public water supply, or whose accomplishments in that field of endeavor, shall entitle him to especial recognition by the Association. Honorary Members shall have the same privileges as Active Members, but shall not be required to make any payments for the support of the Association.

SECTION 3. An Active Member shall be either a Superintendent, Manager or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, a chemist or bacte-

riologist, including those acting technically as such for, and employed by, Associate Members of the Association; or any qualified person engaged in the advancement of knowledge relating to water supplies in general.

SECTION 4. A Corporate Member shall be either a Water Board or Commission, or a Water Company, and shall be entitled to one representative who shall have all the rights and privileges of an Active Member.

SECTION 5. An Associate Member shall be either a person, firm or corporation, engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works. An Associate Membership shall entitle the holder to be represented by one person on the floor at each meeting but such representative shall not be entitled to vote or take part in any discussion unless permission is given by unanimous consent of the members present; provided, however, that Associate Members may vote on selection of the place of meeting as provided in Article 9, Section 1, each Associate membership being entitled to one vote only.

SECTION 6. When an Active Member so changes his vocation that were he to apply for membership he would be classed as an Associate Member, he may continue as an Active Member with all the privileges of that grade, except that he shall not be eligible to any elective office in the Association.

ARTICLE IV

ADMISSION AND EXPULSION

SECTION 1. The Executive Committee may, at its discretion, at the request of any member, present the name of any person qualified for Honorary Membership, to the Association for election to that grade of membership; but the Executive Committee must, upon the written request of twenty-five members, so present the name of any such person to the Association.

SECTION 2. Any person, firm, corporation or water department desiring to become an Active, Corporate or Associate Member must make application for the grade of membership sought, upon the blank form provided by the Association. Each application must be endorsed by two members of the Association, shall embody a concise statement of the applicant's qualifications for membership and be accompanied by the initiation fees and dues as hereinafter

provided. All applications must be forwarded to the Secretary who shall submit them to the Membership Committee, as soon as possible.

A majority affirmative vote of the Membership Committee shall elect to Active, Corporate or Associate Membership subject to review by the Executive Committee.

SECTION 3. No member whose dues are in arrears shall receive the publications of the Association until such dues are paid. Members in arrears for one year shall be dropped from the roll by the Secretary.

SECTION 4. Any member who has been suspended for non-payment of dues may be reinstated by the Membership Committee upon payment of all back dues. He shall then be entitled to receive such back numbers of the publications of the Association as may have been withheld from him on account of non-payment of dues, and are not out of print.

SECTION 5. Any member of any grade may be expelled from the Association for cause, upon the recommendation of the Membership Committee, adopted by a two-thirds vote of the members present and voting at any annual convention.

SECTION 6. Any member may retire from membership by giving written notice to that effect to the Secretary, provided that he pay all dues to that date, unless released from said payment by the Executive Committee.

ARTICLE V

FEES AND DUES

SECTION 1. Each Active Member shall pay an initiation fee of Five Dollars, and annual dues of Five Dollars.

SECTION 2. Each Corporate Member shall pay an initiation fee of Ten Dollars, and annual dues of Five Dollars.

SECTION 3. Each Associate Member shall pay an initiation fee of Ten Dollars, and annual dues of Ten Dollars.

SECTION 4. The fiscal year of the Association shall begin April 1st and terminate on March 31st. Annual dues shall be payable in advance and shall be due on April 1st, the first day of the fiscal year covered by said dues. It shall be the duty of the Secretary to notify each member on or before March 15th of the amount due from said member for the ensuing year.

SECTION 5. Any newly elected member shall be entitled to all the publications of the Association that are distributed to its members during the year. Members elected later than December 1st shall not be required to pay the annual dues for the current year, but if they do pay said annual dues they shall receive all the publications to which members in good standing are entitled for that year.

SECTION 6. In case any application for membership shall be rejected the initiation fee and dues which accompanied the application shall be returned to the applicant.

SECTION 7. Any Active Member in good standing in any Interstate, State or Local Association formed for the same general purpose as this Association, and which has been approved as such by the Executive Committee of this Association, who may apply for Active or Corporate Membership, may be admitted by the Membership Committee without the payment of the regular initiation fee; provided he shall furnish evidence that he has paid, during his membership in such Interstate, State or Local Association, in fees and dues, an amount equal to or exceeding the initiation fee required in this Association, and is at the time of making application for membership in this Association an Active Member in good standing in said Interstate, State or Local Association.

ARTICLE VI

OFFICERS

SECTION 1. The officers of the Association shall be a President, Vice-President, Treasurer, Secretary and Editor of the Association's publications. The offices of the Secretary and Editor may be combined at the discretion of the Executive Committee.

SECTION 2. There shall be an Executive Committee in which the government of the Association shall be vested. It shall consist of the President, Vice-President, Treasurer, Secretary, Editor, the Chairman of the Finance Committee, the latest two living past Presidents and six Trustees elected to represent the six districts hereinafter established, one Trustee to be elected from each district to serve three years. The President and Secretary of the Association shall be the President and Secretary of the Executive Committee.

In 1919 one Trustee shall be elected from District 1, and one from District 4, to succeed the present Trustees whose terms expire in

1919; in 1920 one Trustee shall be elected from District 2, and one from District 5 to succeed the present Trustees whose terms expire in 1920; in 1921 one Trustee shall be elected from District 3, and one from District 6, to succeed the present Trustees whose terms expire in 1921; and every year thereafter two Trustees shall be elected in the districts in which the terms of the incumbents expire.

SECTION 3. The following districts are established for the purpose of territorial representation:

District 1 shall include the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Michigan, Wisconsin and the Dominion of Canada.

District 2 shall include the State of New York.

District 3 shall include the States of New Jersey, Pennsylvania and Delaware.

District 4 shall include the States of Ohio, Indiana and Illinois.

District 5 shall include the District of Columbia and the States of Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Missouri, Tennessee, Kentucky, Arkansas, Louisiana, Kansas, Oklahoma and Texas.

District 6 shall include all other States and Territories of the Union, and all territory outside of the United States not otherwise provided for.

The boundary lines of these districts may be changed by majority vote of the Association at any time when it becomes necessary so to do in order to preserve approximately the same number of voting members in each district. Should any Trustee be thrown into another district by changes made in the boundary lines or by change of residence, he shall serve out his term of office and be accredited as the representative either of his old district or of the district in which he resides, as the Executive Committee may determine.

SECTION 4. On or before the first day of November of each year, the Executive Committee shall appoint a Nominating Committee composed of seven members, one from each district, together with the latest living past-President of the Association, who shall be the Chairman of the Committee. The district members thus appointed shall be those active, honorary or corporate members who receive from their respective districts the largest number of votes of the general membership obtained in the following manner: members from each district present at the annual convention shall submit one name and may submit two, but not more, from members from that district,

as candidates for the Nominating Committee for that district; the names submitted, together with any others sent to the Secretary within sixty days after the annual convention, over the signatures of at least twenty-five voting members from the district for which the candidate is to be elected, shall be printed on a ballot and mailed to the voting membership of each district not later than the first day of October following, but voting shall not be restricted to such names. The polls shall be closed at the Secretary's office at noon October 20th. The said ballots for each district shall have only the names of the candidates for that district printed thereon with space left for inserting another name by the voter. The method of balloting shall be the same as that provided hereafter for election of officers. Should there be a tie vote in any district, the Executive Committee shall decide by vote which of the candidates receiving the largest number of votes shall be appointed.

On or before the first day of January following, the Nominating Committee so elected shall meet at some convenient point for the purpose of selecting nominees for the offices to be filled. Railroad fares of the members of the Committee attending this meeting, on the basis of an allowance of four cents per mile of travel by the shortest route, shall be paid by the Association after the accounts have been approved by the Chairman of the Nominating Committee and by the Finance Committee. The Nominating Committee shall select only one nominee for each office to be filled, after obtaining the consent of the nominee to accept nomination and to serve if elected.

On or before January 10 the Nominating Committee shall report its list of nominees to the Secretary of the Association, who shall before the first day of February cause to be mailed to the membership the list of nominees selected by the Nominating Committee. At any time prior to noon on the first day of March of each year additional nominations may be made by request to the Secretary, signed by at least twenty-five Active, Honorary or Corporate members, and upon the receipt of such request the Secretary shall, after acceptance of the nomination by the candidate, add such additional nominees to the final ballot to be prepared by him. The nominees of the Nominating Committee shall head such final ballot for each office, and any additional nominees for the respective offices shall be placed under the nominees of the Committee in alphabetical order.

SECTION 5. Election shall be by letter ballot. At least two months before the date of the annual convention, a ticket shall be

mailed to each member of the Association entitled to vote. Each member shall be entitled to vote for one candidate for President, one candidate for Vice-President, one candidate for Treasurer and two candidates for Trustees. The ballot shall be sealed separately in a special ballot envelope. This ballot envelope shall be enclosed in a larger envelope and forwarded to the Secretary. The signature of the member voting shall appear on the outer envelope.

The Secretary with two canvassers appointed by the President shall meet at a time and place directed by the President, and shall open and count all ballots cast by persons entitled to vote. No ballot shall be counted if received later than noon of the seventh day previous to the beginning of the annual convention.

The result of the canvass for President, Vice-President, Treasurer and Trustees shall be declared by the President at the Annual Meeting on certification of the canvassing board. The members who shall have received the highest number of votes cast for the several offices shall be declared elected. If there be a tie vote the President shall order a vote to be taken in the annual convention to decide which person of those who shall have received the same number of ballots shall be chosen.

The terms of the officers so elected shall be as follows: For the President, Vice-President, and Treasurer, each one year beginning with the close of the last day of the annual convention and ending the last day of the next annual convention, or until their successor shall have been chosen; for the Trustees, three years beginning with the close of the last day of the annual convention, or until their successors shall have been chosen.

Section 6. Before the close of each annual convention, the Executive Committee elected to serve during the year ensuing, shall organize and elect a Secretary and an Editor, to serve until the close of the next annual convention, or until their successors are chosen.

Section 7. In case of inability of the President to perform the duties of his office, his position shall be temporarily filled by the Vice-President, and in case of inability of the Vice-President, his position shall be filled by one of the Trustees; the order of precedence being governed by priority in date of election as Trustee, or if the dates of election be the same, by priority in date of the admission of such Trustees to membership in the Association.

Section 8. All vacancies in office, except as provided in Section 7 hereof, shall be filled by vote of the Executive Committee for the

unexpired term of said office as soon as practicable after said vacancy occurs.

SECTION 9. The President, Vice-President and Trustees shall be ineligible to election to the same office for consecutive terms.

ARTICLE VII

DUTIES OF OFFICERS

SECTION 1. The President shall have general supervision of the affairs of the Association, and shall preside at all meetings of the Association and of the Executive Committee at which he may be present.

SECTION 2. The Executive Committee shall be the legal representative of the Association and as such shall have full control of the management of the affairs of the Association, subject to the control of the Association in regular convention; it shall make the necessary arrangements for the convention and shall have power to expend the funds of the Association or to invest the same, but must not incur indebtedness beyond the funds in the hands of the Treasurer and Secretary. The Executive Committee shall have power to prepare and enforce, for the conduct of the business of the Association, by-laws not in conflict with this Constitution. It shall hold an annual meeting at least one hour before the opening session of each annual convention. Other meetings shall be held at the call of the President or of any three members of the Executive Committee.

All questions in the Executive Committee shall be decided by a majority vote and seven members shall constitute a quorum. The Executive Committee may vote by letter upon questions submitted by the President and Secretary.

SECTION 3. The Treasurer shall have charge of the funds of the Association, shall pay bills against the Association on order of the Finance Committee certified by the Secretary and shall make a report of the expenditures and of the funds of the Association at the annual convention.

SECTION 4. The Secretary shall be an Active Member of the Association. It shall be his duty to attend all conventions and meetings of the Association and of the Executive Committee; prepare the business and duly record the proceedings thereof. He

shall see that all moneys due the Association are carefully collected, and shall promptly pay the same to the Treasurer. He shall personally certify the accuracy of all bills or vouchers to the Finance Committee.

He shall, at the annual convention, make a report of the receipts and of the condition and affairs of the Association.

He shall conduct the correspondence of the Association and keep a full record of the same.

SECTION 5. The Editor shall have charge of the printing and distribution to all the members, of the Proceedings and Transactions of the Association and shall perform such other duties as are assigned to him by the Executive Committee.

The publications of the Association shall be copyrighted so far as is practicable and proper.

ARTICLE VIII

COMMITTEES

SECTION 1. There shall be four standing Committees, the Finance Committee, the Membership Committee, the Publication Committee and the Convention Committee. The members of each shall be appointed by the incoming Executive Committee. They shall serve for one year beginning with the close of the last day of the Annual Meeting or until their successors shall have been appointed. Special Committees may be appointed at any time by the President.

SECTION 2. The Finance Committee, which shall consist of three active members, shall audit and approve all bills before they shall be paid by the Treasurer. It shall examine the books of the Secretary and of the Treasurer annually or more often, and shall audit the same and report upon the same to the Executive Committee. This Committee shall also have general supervision of the finances of the Association, making such reports thereon to the Executive Committee as the exigencies of the case may require or as directed by the Executive Committee or by the Association at its annual convention.

SECTION 3. The Membership Committee, which shall consist of three members, shall examine the qualifications of and vote upon all applicants for membership nominated in due form, and report its action to the Secretary.

SECTION 4. The Publication Committee, which shall consist of five members, one of whom shall be the Editor, shall have control of the publications of the Association and shall see that all publications and papers are edited before publication, and, whenever possible, before presentation.

The committee may call to its aid members of the Association or others who have had special experience in the subject treated, to advise in regard to any paper, or to discuss the same, and may return any paper to its author for correction or amendment.

No papers containing matter either readily found elsewhere, especially advocating personal interests, carelessly prepared, purely speculative, or foreign to the purpose of the Association shall be accepted. The Committee shall prepare rules which, when approved by the Executive Committee, shall govern the preparation, presentation and publication of all papers and such other matters of similar nature as the best interests of the Association may require.

SECTION 5. The Convention Committee, which shall consist of three members, one of whom shall be the Secretary, shall investigate all invitations to hold conventions of the Association, satisfying itself that the places extending the invitations have proper facilities for the accommodation of the members and guests, for holding the meetings of the Association with its National Sections, and for Exhibits by Associate Members. This Committee shall invite the Convention Committee of the Water Works Manufacturers' Association to coöperate with it. The Committee shall prepare and send to all cities extending invitations to hold conventions a form containing such questions as may be necessary to properly inform the Committee as to the convention facilities offered. The information shall include a diagram of the rooms offered for meeting rooms, Committee and Section rooms and exhibition space, also a list of available hotels, with guaranteed rates and the number that each will accommodate; points of interest to water works people, and entertainment, if any, offered.

During each Annual Convention the Committee shall hold a meeting, at which advocates of various places extending invitations shall be heard, and at the time designated by the Executive Committee for the selection of the place for holding the next Annual Convention the Committee shall make a report to the convention, stating in alphabetical order the invitations received and fully and impartially set forth the advantages and facilities offered by each. Should no invi-

tations be received it shall be the duty of the Committee to ascertain what arrangements can be made for holding a convention, and to report to the Executive Committee before the convention convenes.

The Committee, or one or more members of the Committee, may, as soon as practicable after the place for holding a convention has been selected, visit such place and ascertain whether the guarantees can be fully carried out, and whether it is a suitable place for holding a convention of the Association; also, if the place is approved, to make the necessary arrangments for holding the convention. If, after such visit, it is the judgment of the Committee that the place is not suitable, or does not offer proper facilities, or for any other reason it would not be for the best interests of the Association to hold its convention there, the Committee shall immediately report its findings to the Executive Committee, with its recommendations as to the meeting place for the next annual convention. The expenses of the Committee or members of the Committee, in making such visits to be borne by the Association, on the basis of an allowance of four cents per mile travel.

ARTICLE IX

Meetings

Section 1. The Annual Convention of the Association shall open on such Tuesday as the Executive Committee may designate, at nine o'clock, a. m., and at such place as shall have been designated by the Association at the previous convention, the selection to be by ballot. The place receiving a majority of all votes cast shall be selected as the place of meeting. All members shall be entitled to vote.

Section 2. The Executive Committee shall have power to change the place of meeting as in its judgment the interests of the Association may demand.

Section 3. The date of the Annual Convention shall be fixed by the Executive Committee not less than seventy days in advance of the meeting, and such date shall be printed on all ballots for the nomination or election of officers.

ARTICLE X

Sections

Section 1. Local Sections may be established by the Executive

Committee on receipt of a written request to that effect signed by twenty Active or Corporate Members of the Association, residing in the territory within which the Local Section is desired.

SECTION 2. National Sections consisting of Engineers, Superintendents, Chemists and Bacteriologists, Accountants or other classes of persons included in the membership of the Association, may be established by the Executive Committee on the request of thirty members. Any member of the Association may register in any National Section of the Association in which he is interested.

SECTION 3. Such sections shall choose their own officers and committees and may make any rules for their government not inconsistent with the constitution and by-laws of the Association, but these rules must first be approved by the Executive Committee.

SECTION 4. Each Local Section as soon as established, and after its rules have been approved by the Executive Committee, may, with the approval of the Finance Committee, annually receive from the Treasurer of the Association, for local use, not more than twenty-five per cent of the annual dues paid to the Association by the members of the said Local Section; except that in no case shall the total of all moneys received by any Local Section for any one fiscal year exceed the sum of One Hundred and Fifty Dollars; and except that Local Sections with small memberships, where the allotted twenty-five per cent of the annual dues paid to the Association by the members of the said Local Section does not amount to Fifty Dollars, such Local Sections shall be entitled to receive from the Treasurer of the Association, for local use, not more than Fifty Dollars in any one fiscal year.

The Treasurer of each Local Section shall forward to the Secretary of the Association his application endorsed by the presiding officer of the Section for such portions of the said sums above specified as may be needed; and upon receipt of such application the Secretary shall request the Finance Committee to authorize the Treasurer of the Association to pay such sums to the Treasurer of the Local Section. These moneys may be used by the Local Section only in payment of necessary operating expenses incurred by the Section, such as printing, stationery, postage, rent and care of meeting room, light, fuel, stenographer, and stereopticon operator services at meetings, etc.

At the end of each fiscal year the Treasurer of each Local Section shall submit a certified copy of his accounts to the Secretary of the Association, the same being itemized and showing the balance on

hand of the funds received from the Association. This balance shall be returned to the Secretary of the Association, or shall be charged to the Local Section as a portion of its quota for the following year.

SECTION 5. The presiding officer of each section shall be an Honorary Vice-President of the Association.

SECTION 6. Any section may be dissolved by the Executive Committee for good and sufficient reasons.

ARTICLE XI

GENERAL

SECTION 1. Any member may, with the concurrence of the presiding officer, admit friends to the meetings of the Association, but such persons shall not take part in the discussions without the consent of the convention; and the privilege of the floor can only be granted to a non-member by unanimous consent.

SECTION 2. The Secretary shall send notice to all members of the Association at least fifteen days before the annual convention, giving the titles of papers to be read and mentioning any special business to be considered at said convention.

ARTICLE XII

AMENDMENTS

SECTION 1. All proposed amendments to the Constitution shall be submitted in writing to the Executive Committee which at its discretion may bring them before the next Annual Convention of the Association, but the Executive Committee must do so on the request in writing of five members of the Association.

SECTION 2. To pass an amendment to the Constitution, an affirmative vote of two-thirds of the members present and voting at said convention shall be required.

PAST PRESIDENTS

*Col. J. T. Foster, Chicago, Ill	1881–1882
*Col. J. T. Foster, Chicago, Ill	1882–1883
*J. G. Briggs, Terre Haute, Ind	1883–1884
*L. H. Gardner, New Orleans, La	1884–1885
*Peter Milne, Brooklyn, N. Y	1885–1886
†B. F. Jones, Kansas City, Mo	1886–1887
*J. T. Fanning, Minneapolis, Minn	1887–1888
†A. N. Denman, Des Moines, Ia	1888–1889
*J. H. Decker, Salina, Kans	1889–1890
†William B. Bull, Quincey, Ill	1890–1891
J. M. Diven, Elmira, N. Y	1891–1892
G. H. Benzenberg, Milwaukee, Wis	1892–1893
James P. Donahue, Davenport, Ia	1893–1894
*William Ryle, Paterson, N. J	1894–1895
*W. G. Richards, Atlanta, Ga	1895–1896
*F. A. W. Davis, Indianapolis, Ind	1896–1897
John Caulfield, St. Paul, Minn	1897–1898
*Joseph A. Bond, Wilmington, Del	1898–1899
R. M. Clayton, Atlanta, Ga	1899–1900
C. E. Bolling, Richmond, Va	1900–1901
*William R. Hill, New York, N. Y	1901–1902
*C. H. Campbell, Charlotte, N. C	1902–1903
†L. N. Case, Duluth, Minn	1903–1904
Morris R. Sherrerd, Newark, N. J.	1904–1905
†Benjamin C. Adkins, St. Louis, Mo	1905–1906
Dabney H. Maury, Peoria, Ill	1906–1907
George H. Felix, Reading, Pa	1907–1908
D. W. French, Weehawken, N. J	1908–1909
Dr. William P. Mason, Troy, N. Y	1909–1910
John W. Alvord, Chicago, Ill	1910–1911
Alexander Milne, St. Catharines, Ont	1911–1912
Dow R. Gwinn, Terre Haute, Ind	1912–1913
Robert J. Thomas, Lowell, Mass	1913–1914
George G. Earl, New Orleans, La	1914–1915
Nicholas S. Hill, Jr., New York, N. Y	1915–1916
Leonard Metcalf, Boston, Mass	1916–1917
Theodore A. Leisen, Detroit, Mich	1917–1918

* Deceased.

† Not now a member of the Association.

LIST OF OFFICERS 1918–1919

President

CHARLES R. HENDERSON, Manager Davenport Water Co., Davenport, Ia.

Vice-President

CARLETON E. DAVIS, Chief, Bureau of Water, Philadelphia, Pa.

Treasurer

JAMES M. CAIRD, Chemist and Bacteriologist, Troy, N. Y.

Secretary

JOHN M. DIVEN, Superintendent of Water Works, Troy, N. Y.

Editor

J. M. GOODELL, Washington, D. C.

Trustees

Term Expiring 1919

M. L. WORRELL, General Manager Water Department, Meridian, Miss.
F. W. CAPPELEN, City Engineer, Minneapols, Minn.

Term Expiring 1920

BEEKMAN C. LITTLE, Superintendent Water Works, Rochester, N. Y.
W. S. CRAMER, Chief Engineer Water Works Company, Lexington, Ky.

Term Expiring 1921

ALLAN W. CUDDEBACK, Engr. and Supt. Water Company, Paterson, N. J.
JACK J. HINMAN, JR., State Board of Health, Iowa City, Ia.

Executive Committee

CHARLES R. HENDERSON, President

CARLETON E. DAVIS	JOHN M. GOODELL
JAMES M. CAIRD	M. L. WORRELL
JOHN M. DIVEN	F. W. CAPPELEN
GEORGE A. JOHNSON	B. C. LITTLE
LEONARD METCALF	W. S. CRAMER
THEODORE A. LEISEN	ALLAN W. CUDDEBACK

JACK J. HINMAN, JR.

LIST OF COMMITTEES 1918–1919

FINANCE

GEORGE A. JOHNSON, Chairman, 150 Nassau St. New York, N. Y.
J. WALDO SMITH, Municipal Building, New York, N. Y.
FRANK A. BARBOUR, 1120 Tremont Building, Boston, Mass.

PUBLICATION

CHARLETON E. DAVIS, Chairman, Chief, Bureau of Water, Philadelphia, Pa.
WILLIAM W. BRUSH, Municipal Building, New York, N. Y.
ALLAN W. CUDDEBACK, 158 Ellison St., Paterson, N. J.
GEORGE A. JOHNSON, 150 Nassau St., New York, N. Y.
JOHN M. GOODELL, Editor, Cosmos Club, Washington, D. C.

MEMBERSHIP

LEWIS I. BIRDSALL, Chairman, Superintendent Filtration, Minneapolis, Minn.
FRANK C. JORDAN, Secretary Water Company, Indianapolis, Ind.
W. Z. SMITH, General Manager Water Works, Atlanta, Ga.

CONVENTION

BEEKMAN C. LITTLE, Chairman, Supt. Water Works, Rochester, N. Y.
DR. M. P. CONWAY, Auburn Water Board, Auburn, N. Y.
JOHN M. DIVEN, Secretary, Superintendent Water Works, Troy, N. Y.

REVISION OF STANDARD SPECIFICATIONS FOR CAST IRON PIPE AND SPECIALS

JOHN H. GREGORY, Chairman, Cons. Engr., 170 Broadway, New York, N. Y.
W. H. RANDALL, Supt. of Maintenance, Water Dept., Toronto, Ont.
WALTER WOOD, Prest. Millville Water Co., 400 Chestnut St., Philadelphia, Pa.
FRANK A. BARBOUR, Cons. Hydr. and Sanit. Engr., 1120 Tremont Bldg., Boston, Mass.
EDWARD E. WALL, Water Commissioner, St. Louis, Mo.
N. F. S. RUSSELL, 1421 Chestnut Street, Philadelphia, Pa.

OFFICIAL STANDARDS OF WATER ANALYSIS

JACK J. HINMAN, JR., Chairman, State Board of Health, Iowa City, Ia.
E. M. CHAMOT, Prof. Sanitary Chemistry, Cornell Univ., Ithaca, N. Y.
H. A. WHITTAKER, State Board of Health, Minneapolis, Minn.
JOSEPH RACE, City Bacteriologists and Chemist, Ottawa, Can.
ABEL WOLMAN, Sanitary Engineer, 16 W. Saratoga Street, Baltimore, Md.

COLD WEATHER TROUBLES

CHARLES R. BETTES, Chairman, Ch. Eng. Queens Co. Water Co., Far Rockaway, N. Y.
EDWARD S. COLE, 25 Elm Street, New York, N. Y.
CARLOS LOBO, Dept. W. S. G. & E., Municipal Building, New York, N. Y.
JOHN H. COOK, Hyd. Engineer, 158 Ellison St., Paterson, N. J.
FRANCIS H. LUCE, Superintendent Water Company, Woodhaven, N. Y.

PRIVATE FIRE PROTECTION SERVICE

NICHOLAS S. HILL, JR., Chairman, Consulting Engineer, 100 William Street, New York, N. Y.
GEORGE G. EARL, 502 City Hall Annex, New Orleans, La.
E. V. FRENCH, M.E., 31 Milk Street, Boston, Mass.
FRANK C. JORDAN, Secretary Water Company, Indianapolis, Ind.
WALTER E. MILLER, 1719 Madison Street, Madison, Wis.

ROLL OF HONOR

BABBITT, HAROLD EATON, Capt. E. R. C., A. S., S. O. S., Am. Exp. Forces.
BARTOW, EDWARD, Major San. Corps, N. A., Am. Exp. Forces.
BASCOM, G. R., Major San. Corps, Camp Pike, Ark.
BASSETT, CHARLES K., 1st Lieut. Eng. Div. Ord., Am. Exp. Forces.
BENNETT, A. N., 1st Lieut. 337th F. A. R. C., Camp Dodge, Ia.
BLACK, ERNEST B., Capt. Aviation Sect. Signal Corps, Washington, D. C.
BLACK, GURDON G., Major Engrs. N. A. 314th Engineers (Sappers), Amer. Exp. Forces.
BLAIR, MCCREA PARKER, Capt. Conmdg. Co. C, No. 1 Depot Battalion. Minto Barracks, Winnipeg, Man.
BOWLES, JAMES TEN BROECK, Lieut.-Col. San. Corps, Am. Exp. Forces.
BRENNAN, B. C., Capt. Eng. Corps, Am. Exp. Forces.
BROWN, RASSELAS WILCOX, Co. A, 112th U. S. Inf., Camp Hancock, Ga.
BROWN, ROBERT HUSE, Capt. San. Corps, N. A., Camp A. A. Humphreys, Va.
BUSWELL, A. M. Lieut. San. Med. Corps, Am. Exp. Forces.
CARR, JOSEPH ARTHUR, Corp. Aviation Sect. Signal Corps, Amer. Exp. Forces.
CASE, RALPH E., Ensign Naval Reserve, New London, Conn.
CATLETT, GEORGE FITZHUGH, Capt. San. Eng., Amer. Exp. Forces.
CHENEY, JOSEPH Y., 2nd Lieut. Co. D, 17th Inf., Tampa, Fla.
CHRISTIE, J. G. C., Lieut., 505 Aero Squad., Camp Greene, Charlotte, N. C.
CLAIBORNE, HERBERT A., Lieut. 485 Aero Squad., Am. Ex. Forces.
CURRY, DR. D. P., Capt. Asst. Chf. Med. Of. Canal Zone, Balboa Heights, C. Z.
DANIELS, FRANCIS E., Capt. San. Corps, Camp Lee, Va.
DIVEN, JOHN M., JR., 2nd Lieut. O. R. C., Edgewood Arsenal, Edgewood, Md.
DOTEN, LEONARD S., Major Q. M. C., N. A., Washington, D. C.
DUSINBERRE, GEORGE B., Major O. R. C., Washington, D. C.
FERGUSON, HARRY FOSTER. 1st Lieut. E. R. C., A. S., S. O. S., Am. Exp. Forces.
FRITZE, L. A., 1st Lieut. Field. Lab. 42nd Div. Rainbow, Am. Exp. Forces.
GAVETT, WESTON, 1st Lieut. San. Corps, Cmndg. San. Squad No. 1, 28th Div., Camp Hancock, Ga.
GOLDSMITH, CLARENCE, Major Q. M. C., N. A., Constr. Div., Washington, D. C.
GRAFF, GEORGE W., 40th Co., 10th Tr. Bat., Camp Lee, Va.
HALE, RICHARD KING, Lieut.-Col. 101st Field Art., Am. Exp. Forces.
HANSEN, PAUL, Capt. Engrs., Am. Exp. Forces.
HASKINS, C. A., Capt. San. Corps, N. A., Washington, D. C.
HAZLEHURST, JAMES NISBET, Major E. R. C., Genl. Staff, Am. Exp. Forces.
HENDRICK, WALLACE M., 1st Lieut. 301st Engrs., Am. Exp. Forces.

HINMAN, JACK, JR., 1st Lieut. San. Corps, N. A. Army Med. School, Washington, D. C.

HYDE, CHARLES GILMAN, Capt. San. Corps, N. A. Camp Greenleaf, Ga.

IRVING, THOMAS C., Lieut.-Col. Royal Canadian Engrs., killed in action October 30, 1917.

IRWIN, RALPH EDWARD, Capt. San. Corps, N. A., U. S. Filling Plant, Edgewood, Md.

JARVIS, ALEXANDER CHARLES, Capt. Royal Engrs., War Office, London, England.

JOHNSON, GEORGE A., Major Q. M. C., N. A., M. & R. Bch. Const. Div., Washington, D. C.

KILPATRICK, JOHN DOUGLAS, Lieut.-Col., Q. M. C. N. G. U. S., Am. Exp. Forces.

KIRKPATRICK, EARL T., Lieut. Co. H. 42d Inf., Newport News, Va.

LEE, CHARLES H., Engrs. 1st Lieut. E. R. C., Water Sup. Section, Am. Exp. Forces.

LEISEN, THEODORE A., Major Q. M. R. C., Constr. Q. M., Camp Custer, Mich.

LETTON, HARRY PIKE, Capt. San. Engr. U. S. R., Water Sup. Sect., Am. Exp. Forces.

LONGLEY, FRANCIS F., Lieut.-Col. 26th Engrs., Am. Exp. Forces.

LONGLEY, FREDERICK J., Lieut. Comndg. Officer, 271st Aero Squad, Ellington Field, Tex.

McCORMICK, ROBERT, Co. D, 26th Engrs., Camp Dix, N. J.

McLAUGHLIN, GEORGE E., Lieut. U. S. Navy, Asst. Surgeon, Naval Tr. Station, Hampton Roads, Va.

McRAE, HENRY C., 1st Leiut. E. O. R. C., 318 Engrs., Van Couver Barracks, Wash.

MACHEN, HENRY B. Ord. Production Div., Explosives Sect., Buffalo, N. Y.

MALLALIEU, WILLARD C., Capt. S. C., N. A., Battalion 7, M. O. T. C., Camp Greenleaf, Ga.

MAURY, DABNEY, H., Lieut.-Col. Q. M. C., N. A., Advisory Engr. Water Sup. Cons. Div., Washington, D. C.

MESSER, RICHARD, Major Q. M. C., N. A. Cons. Div. M. & R. Bch., Washington, D. C.

MITCHELL, CHARLES H., Lieut.-Col., D. S. O., C. M. G., Chief of Intelligence, 2nd British Army, Brit. Exp. Forces. Honors: Distinguished Service Order; Companion of St. Michael & St. George; Officer Legion of Honour (France); Officer Order of Leopold (Belgium); three mentions.

MITCHELL, GEORGE, Lieut. R. M. Engrs. H. M. S. *Impérieuse*, London, England.

MOHLER, BRUCE M., Capt. San. Corps, N. A., Am. Exp. Forces.

MURPHY, ALVIN R., Capt. E. R. C., Am. Exp. Forces.

MURRAY, HARRY E., Capt. Q. M. C., Scofield Barracks.

PIRNIE, MALCOM, 1st Lieut. R. T. C., N. A., Am. Exp. Forces.

POWERS, JEROME, 1st Lieut. U. S. E. R., 24th Engrs., Am. Exp. Forces.

PUGH, MARSHALL R., Major 21st Engrs., Am. Exp. Forces.

RUTTAN, H. N., Brig. Genl. Comndg. M. D. 10, Winnipeg, Man.

SCHARFF, MAURICE ROOS, 1st Lieut. E. O. R. C., Am. Exp. Forces.

SMITH, MERRITT H., Col. 104th Field Art., Am. Exp. Forces.

SMOOT, L. D., Capt. Q. M. C. N. A., Camp A. A. Humphreys, Va.
SPEAR, WALTER E., Major Q. M. C., in chge. Utilities, Camp Upton, N. Y.
STEPHEN, CHARLES, Lieut. Comdg. H. M. S. "Skate," London, England.
SUTER, RUSSELL, Capt. E. R. C., Am. Exp. Forces.
TOLLES, FRANK C., 1st Lieut. Co. E, 112th Engrs., Amer. Exp. Forces.
TOYNE, JOHN W., Capt. Q. M. C., Camp Custer, Mich.
VAN WINKLE, WALTER H., JR., 1st Lieut. Q. M. C., Const. Div., Washington, D. C.
WALKER, ELTON D., Capt. Co. A, 15th Engrs., Am. Exp. Forces.
WEST, VERNON F., Lieut. U. S. Navy, Portland, Me.
WHEELER, ROBERT C., Capt. Q. M. C., Newport News, Va.
WHITMAN, EZRA B., Major O. R. C., Camp Meade, Md.
WICKHAM, JAMES T., Royal Engrs., British Army.
WOOD, EDWARD R., JR., Capt. 118th Field Art., Am. Exp. Forces.
WORRELL, M. L., Capt. Q. M. C. N. A., Camp Logan, Texas.
WRIGHT, JOHN BERTRAM, Capt. Co. C, 520 Engrs. Camp, A. A., Humphreys, Va.

JUNIOR ROLL OF HONOR

AMSBARY, HARLOW A. (son F. C.), 2nd Lieut. 30th Artillery Brig., C. A. C. Am. Exp. Forces.
ATKINSON, MYRON H. (son T. R.), 3rd O. T. C., Camp Devens Mass.
BAKER, FREDERICK W. (son M. N.), 2nd Lieut. 62nd Inf., Camp Gordon, Ga.
BATCHELDER, ROBERT F. (son G. W.), Ensign N. R. F.
BERRY, LOREN J. (son J. P.), 1st Sgt. M. C., Am. Exp. Forces.
CLARK, DONALD M. (son H. W.), Co. C 73rd U. S. M. C., Paris Island, S. C.
CLOW, WILLIAM E. (son J. B.), Ensign U. S. Navy, Lake Forest, Ill.
DAPPERT, ANSELMO F. (son J. W.), Lt. 305th Tank Battalion, Co. A, Camp Colt, Pa.
DAPPERT, BOYD H. (son J. W.) 21st, 6th Tr. Bri. 157 Depot, Camp Gordon, Ga.
DAPPERT, JAMES IVAN (son J. W.) Sgt. 132nd U. S. Inf., Am. Exp. Forces.
DAPPERT, JOHN V. (son J. W.), Lieut. 130th U. S. Inf., Am. Exp. Forces.
DAPPERT, MERLIN L. (son J. W.), Lieut. Co. I, 130th U. S. Inf., Am. Exp Forces.
FALLER, C. P. (son C.), Lieut. 11th Inf., Camp Forest, Ga.
FELLOWES, A. N. (son C. L.), Lieut. Railway Bat., Can. Exp. Forces.
FELLOWES, C. O. (son C. L.), Lieut. Sig. Of. 3rd Canadian Inf. Brigade.
FELLOWES, K. C. (son C. L.), Lieut. Inf. Can. Exp. Forces, France.
FELLOWES, S. H. (son C. L.), Capt. 8th Field Co. of Engrs., Can. Exp. Forces, France.
GOODELL, JOHN B. (son J. M.), U. S. N. R., Fore River Shp. Bldg. Co., Quincy, Mass.
GOODRICK, EDGAR CEPHUS (son E. H.), Chf. Q. M. Signals, U. S. N., in foreign waters.
GRASTY, R. L. (son E. C.), Co. L, 158 Inf., Camp Kearny, Cal.
GWINN, LAWRENCE R. (son D. R.), Meteorology Div., College Station, Tex.
GWINN, PAUL C. (son D. R.), Gas Defense Div., New Haven, Conn.
HOWELL, BEAUDRIC L. (son D. J.), Co. E, 104th U. S. E. R., Am. Exp. Forces.

HULICK, WILLIAM H., JR. (son W. H.), on Destroyer in foreign waters.
HYMMEN, GORDON (son H.), Co. A. Royal Can. Inf. Military Hosp., Guelph, Ont.
IRWIN, C. RUSSEL (son T. C.), San Detch. 102nd Fld. Sig. Bn., Am. Exp. Forces.
JOHNSON, GEORGE S. (son Peter), Lieut. Aviation, Pine Field, West Point, Miss.
KENT, W. T. (son J. T.), Naval Aviation, N. F. R., Am. Exp. Forces.
LEISEN, THEODORE A., JR. (son T. A.), Navy, U. S. S. "DeKalb."
LITTLE, DAVID BEEKMAN (son B. C.), U. S. N. R. Naval Station, Pelham Bay, N. Y.
LUCAS, DANIEL R. (son H. L.), Corp. Engrs. Co. A, 108th Engrs., Am. Exp Forces.
LUCE; HERBERT P. (son F. H.), Capt. Co. C, 305th Machine Gun, Am. Exp. Forces.
LUCE, ROBERT F. (son F. H.), Flying Cadet, Mineola, N. Y.
McWILLIAMS, JOHN S. (son C. Q.), 1st Lieut. Aviation, Am. Exp. Forces.
MAURY, DABNEY H., JR. (son D. H.), U. S. A. A. C., S. S. V. 623 Am. Exp. Forces.
MILLER, BUCKINGHAM (son H. A.), Co. A. 27th Engrs., Am. Exp. Forces.
MILLER, DONALD F. (son S. F.), Ensign (T) U. S. N., Submarine School, New London, Conn.
MILLER, HIRAM ALLEN, JR. (son H. A.), Hdqtrs. 5th Field Art., Am. Exp Forces.
MILLER, PHILIP F. (son S. F.) 1st Lieut. Ord. Engrs., Washington, D. C.
MILLIGAN, ARCHIBALD S. (son R.E.), Inf., Camp Funston, Kans.
MORRIS, CHARLES (son C. H.), Co. H, 113th Inf., Camp Hill, Newport News, VA.
MORRIS, LEROY H. (son C. H.), Co. H, 113th Inf., Camp Hill, Newport News Va.
MORRIS, RUSSEL H. (son C. H.), Co. G, 311 Inf., Am. Exp. Forces.
MUELLER, LUCIEN W. (son Philip), Lieut. Ord. Dept., Detroit, Mich.
MUELLER, WILLIAM EVERETT (son Adolph), U. S. N. R., Pelham Bay, N. Y.
RANDALL, W. T. (son W. H.), 4th Can. Battalion, Can. Exp. Forces.
RUE, ORLIE (son J. A.), 1st Sgt. Signal Corps, Camp S. F. B. Morse, Tex.
RUST, FRED C. (son C. H.), 16th Can. Reserve Battalion, Brit. Exp. Forces.
RYLAND, REIS J. (son J. R.), 2nd Lieut. U. S. R., S. C., Camp McArthur, Tex.
VOLKHARDT, A. N. (son Wm.), 2nd Lieut. S. C., Aero Sec. Schl. of Aviation, Ithaca, N. Y.
WILCOX, WILLIAM F., JR. (son W. F.), Sgt. 106th Supply Train, 31st Div.
WYNNE-ROBERTS, MISS BUDDUG (daughter R. O.), Nurse, St. John's Ambulance, Rouen, France.
WYNNE-ROBERTS, LEWIS WYNNE (son R. O.), Royal Engrs. Indian Army, 9th Co., Queen Victoria's Own Sappers and Miners, Mesopotamia Exp. Forces, Mesopotamia.
YEREANCE, ALEXANDER W. (son W. B.), 1st Lieut. Co. F, 305th Engrs., Am. Exp. Forces.

LIST OF MEMBERS

HONORARY MEMBERS

	DATE OF ADMISSION
Bement, R. B. C. St. Paul, Minn.	Apr. 18, 1888
Cameron, William L. 2415 Ave. K, Galveston, Tex.	Mch. 29, 1881
Caulfield, John Mgr. Bismarck Water Supply Co., Bismarck, N. D.	July 14, 1887
Holly, Ira A. 223 Clinton Ave., New Haven, Conn.	Mch. 29, 1881
Holman, M. L. 721 Olive St., St. Louis, Mo.	Mch. 29, 1881
LeConte, L. J. C. & Cons. Engr., 2501 Piedmont Ave., Berkeley, Cal.	July 26, 1886
Nakajima, Y. Imperial University, Tokyo, Japan.	July 14, 1887

ACTIVE MEMBERS

Abbott, G. H. Treas. & Supt. Southbridge Water Supply Co., Southbridge, Mass.	June 4, 1912
Ackerman, J. Walter Supt. Water Board, Auburn, N. Y.	June 24, 1918
Adams, Alton D. Public Service Engineer, Natick, Mass.	June 4, 1912
Adams, Henry Cons. Engr., 1263–69 Calvert Bldg., Baltimore, Md.	Apr. 22, 1914
Aeryns, Albert Nelson 716 Greenwood Ave., Brooklyn, N. Y	Mch. 4, 1915
Ahearn, John T. 1903 Adelicia St., Nashville, Tenn.	June 7, 1914
Aldrich, A. C. Supt. of Sts., Rm. 3, City Hall, Beardstown, Ill.	May 29, 1916

ALEXANDER, MONTGOMERY Chem. & Bact., 1224 Washington St., Wilmington, Del.	Apr. 22, 1914
ALLEN, HUGH L. Supt. Water & Light Com., Greenville, N. C.	Apr. 5, 1917
ALLEN, WILLIAM JOHN Ch. Engr. & Bact., 329 Cory Ave., Waukegan, Ill.	Mch. 4, 1915
ALLIN, T. D. Comnr. Pub. Wks., City Hall, Pasadena, Cal.	July 12, 1906
ALLISON, JAMES E. 300 Security Bldg., St. Louis, Mo.	June 24, 1913
ALVORD, JOHN W. Cons. Engr., 1417-18 Hartford Bldg., Chicago, Ill.	May 17, 1889
AMES, CLARENCE F. Supt. Water Works, Norwich, N. Y.	Apr. 10, 1918
AMISS, THOMAS L. Supt. Water and Sewerage, Shreveport, La.	June 26, 1918
AMOS, JOHN F. Ch. Engr. R. & L. O. Water Co., Charlotte Stn., Rochester, N. Y.	June 8, 1908
AMSBARY, F. C. Mgr. Water Co., Champaign, Ill.	June 11, 1902
ANDERS, FRANK LAFAYETTE City Engineer, Box 185, Fargo, N. D.	June 10, 1911
ANDERSON, J. F. 417 N. Denver Ave., Kansas City, Mo.	June 24, 1913
ANDERSON, ROBERT M. Prof. Engrg. Practice, Stevens Inst., Hoboken, N. J.	Dec. 20, 1916
ANDERSON, W. F. Supt. Water Works, Effingham, Ill.	May 12, 1914
ANDREWS, GEORGE C. Water Comnr., 2 Municipal Bldg., Buffalo, N. Y.	Feb. 20, 1917
ANDREWS, LEWIS P. Mgr., Secty. & Treas. Water Co., Sedalia, Mo.	June 7, 1904
ANDREWS, ROBERT E. Natl. Bd. Fire Underwriters, 76 William St., New York, N. Y.	June 24, 1913
ANGIER. E. E. Chmn. Bd. Water Comrs., 117 E. 7th St., Beardstown, Ill.	June 26, 1918
ANGUS, ROBERT W. Prof. of Mech. Engrg., Univ. of Toronto, Toronto, Can.	Jan. 29, 1917

ANTHONY, CHAS. Genl. Mgr. Water Co., Cassilla Correo 149, Bahia Blanca, Argentine Republic, S. A.	July 18, 1907
APPLEBAUM, SAMUEL BERNARD, C.E. San. Engr., 259 E. 182d St., New York, N. Y.	May 3, 1916
ARCHER, ELMER T. Cons. Engr., New England Bldg., Kansas City, Mo.	June 26, 1918
ARMSTRONG, JAMES W., C.E. Lake Montebello, Hillen Rd., Baltimore, Md.	Apr. 27, 1910
ARMSTRONG, RAY Supt. Water & Sewer Dept., Rome, N. Y.	Apr. 22, 1914
ARMSTRONG, ROGER W. Camp Quartermaster's Office, Camp Upton, N. Y.	Apr. 14, 1916
ATKINSON, T. R. Cons. Engr., Bismarck, N. D.	June 24, 1915
ATTERSALL, CHARLES F. Supt. Water Works, Winchester, Ky.	July 18, 1907
AYRES, JOHN H. 208 School St., Bennington, Vt.	May 12, 1908
AYRES, LOUIS E., C.E., B.S. Cornwell Bldg., Ann Arbor, Mich.	Nov. 19, 1914
AYRES, THOMAS H. 905 Sherman Ave., South Bend, Ind.	June 24, 1913
BABBITT, HAROLD E. Capt. Engrs. Res. A. S., S. O. S., Am. Exp. Forces, France.	Jan. 12, 1915
BABCOCK, G. H. Supt. Water Works, East Rochester, N. Y.	June 8, 1916
BACHMAN, FRANK Chem. & Bact., State Bd. of Health, Berkeley, Cal.	Apr. 21, 1915
BAIN, ERNEST B. Supt. City Water Dept., Raleigh, N. C.	June 7, 1904
BAIR, MAURICE Z. Prin. Asst. Engr. State Bd. of Health, Page Hall, Ohio State Univ., Columbus, Ohio.	May 8, 1915
BAKER, M. N. Assoc. Editor *Engineering News-Record*, 10th Ave. at 36th St., New York, N. Y.	June 24, 1903
BALDWIN, FRED N. Supt. Water Works, Flint, Mich.	May 14, 1915
BALDWIN, HENRY DEFOREST Prest. Queens Co. Water Co., 49 Wall St., New York, N. Y.	Apr. 27, 1910

BANCROFT, LEWIS M. — June 27, 1905
Supt. Water Works, Reading, Mass.

BARBOUR, FRANK A. — July 10, 1906
Cons. Hyd. & San. Engr., 1120 Tremont Bldg., Boston, Mass.

BARCLAY, W. E. — June 26, 1918
Supt. Dept. Water and Elect., Aurora, Ill.

BARDWELL, R. C. — Nov. 1, 1914
Chemist, Mo. Pac. Ry. Co., 627 Midland Bldg., Kansas City, Mo.

BARLOW, J. E. — May 14, 1915
C. & Hyd.Engr., Serv. Dir., City Hall, Dayton, Ohio.

BARNES, T. HOWARD, — Jan. 12, 1915
Cons. Engr., United Fruit Co., 1646 Whitehall Bldg., New York, N. Y.

BARNHARD, P. — Oct. 23, 1914
Mgr. Mt. Carmel Pub. Util. Co., Mt. Carmel., Ill.

BARR, WILLIAM M. — Feb. 19, 1917
Con. Chem., U. P. R. R. Co. & O. S. L. R. R. Co., Omaha, Neb.

BARRETT, CHARLES F. — June 24, 1913
Supt. Water Works, City & Co. Bldg., Salt Lake City, Utah.

BARTLETT, N. EMORY — June 8, 1909
Natrona Water Co., 1000 Widener Bldg., Philadelphia, Pa.

BARTOW, EDWARD — July 10, 1906
Major San. Corps, N. A., Am. Exp. Forces, France

BASCOM, G. R. — Sept. 19, 1914
Major San. Corps, N. A., Camp San. Engr., Camp Pike, Ark.

BASS, FREDERICK H. — July 18, 1907
429 Union St., Minneapolis, Minn.

BASSETT, CARROL P., C.E. — July 10, 1906
Treas. Commonwealth Water & Lt. Co., Summit, N. J.

BASSETT, GEORGE B., C.E. — June 15, 1898
691 W. Ferry St., Buffalo, N. Y.

BATCHELDER, GEORGE W. — May 12, 1914
Water Comnr., 19 City Hall, Worcester, Mass.

BATON, WARREN U. C. — July 18, 1907
Chief Analyst, 528 South Lang Ave., Pittsburgh, Pa.

BAUEREISEN, R. J., M.E. — Aug. 24, 1915
C. P. Brant & Co., 710 Marquette Bldg., Chicago, Ill.

BAYLIS, JOHN R. Chem., Baltimore Filt. Plant, 3402 Harford Ave., Baltimore, Md.	Oct. 26, 1915
BEAN, GEORGE L., C.E. 1729 N. 19th St., Philadelphia, Pa.	Dec. 29, 1913
BEARDSLEY, JOSEPH C. P. O. Box 237, Cleveland, Ohio.	June 24, 1903
BECK, F. E. Chf. Engr., Consolidated Water Co., Utica, N. Y.	May 14, 1915
BEDELL, JAMES Supt. Water Works, 10 Croton Ave., Ossining, N.Y.	May 12, 1908
BEITER, G. C. Water Supt., Carroll, Iowa.	May 13, 1916
BELL, DAVID V. Supt. Water Co., U. P. R. R. Co., 325 N. Front St., Rock Springs, Wyo.	June 8, 1909
BEMIS, EDWARD W. City Hall Square Bldg., Chicago, Ill.	June 24, 1903
BENNETT, A. N. 1st Lieut., 337th F. A. R. C., Camp Dodge, Ia.	Feb. 5, 1917
BENNETT, C. G., M.E. State Pub. Util. Comn., 820 So. 7th St., Springfield, Ill.	Apr. 23, 1915
BENZENBERG, G. H. Cons. Engr., 1310 Wells Bldg., Milwaukee, Wis.	Apr. 18, 1888
BERGAN, PATRICK H. Supt. Works, Mount Union, Pa.	Apr. 22, 1914
BERNHAGEN, LEWIS O. Chem. & Asst. Supt. Filtn. Plant, 1502 Second Ave., South, Minneapolis, Minn.	Mch. 3, 1917
BERRY, FRED D. Secty. Bd. Water Comrs., Hartford, Conn.	Mch. 26, 1918
BERRY, J. P. Supt. Water Works, Waterloo, Iowa.	May 26, 1896
BETTES, CHARLES R. Chf. Engr. Queen Co. Water Wks., Far Rockaway, N. Y.	June 18, 1901
BEYER, ALBIN H., C.E. Assoc. in Civ. Eng., Columbia University, New York, N. Y.	June 8, 1916
BIGGS, GEORGE W., JR. Chf. Engr. Amer. Water Wks. & Elect. Co., 50 Broad St., New York, N. Y.	June 2, 1916

Birdsall, Lewis I. Supt. of Filt., Minneapolis, Minn.	June 24, 1913
Birkinbine, Carl P. Hyd. Engr., Parkway Bldg., Philadelphia, Pa.	May 24, 1914
Bishop, Wesley Genl. Supt., Township of Chester Water Dept., Moorestown, N. J.	Apr. 4, 1916
Bishop, William Doylestown, Bucks Co., Pa.	May 12, 1908
Bitgood, Frederick C., M.E. 1308 Traction Bldg., Cincinnati, Ohio.	June 10, 1911
Bixby, Madeleine (Miss) Chemist, 70 Pleasant St., North Andover, Mass.	Feb. 11, 1917
Black, Ernest B. Capt. Aviation Sec. Sig. Corp., Act. Eng. War Credits Bd.. Washington, D. C.	June 24, 1913
Black, Gurdon G. Maj. 314th Eng. Sappers, Am. Exp. Forces, France.	May 8, 1915
Blair, McCrea Parker Capt. Comndg. Co. C, No. 1 Depot Battalion, Minto Barracks, Manitoba.	Apr. 7, 1910
Blake, C. H. M. Calle de la Reforma, 717 Guadalajara, Mex.	July 10, 1906
Blakeman, S. R. Supt. Water & Lt. Dept., Dyersburg, Tenn.	Nov. 1, 1914
Blakemore, Robert B. Comnr. of Water & Sewage, Box 136, Fargo, N. D.	May 14, 1915
Bleistein, Bernard J. Asst. Engr., Dept. W. S. G. & E. of N. Y. City, 240 Jamaica Ave., Long Island City, N. Y	May 7, 1918
Bliven, Charles H. Supt. Norfolk Co. Water Co., Norfolk, Va.	May 12, 1916
Bliven, George H. Supt. R. & L. O. Wtr. Co., 440 Powers Bldg., Rochester, N. Y.	July 18, 1917
Blomquist, H. F. City Engineer, City Hall, Mankato, Minn.	Apr. 3, 1917
Blossom, Francis Engr. & Contr., 52 William St., New York, N. Y.	July 10, 1906
Boardman, W. H., C.E. 426 Walnut St., Philadelphia, Pa.	Sept. 7, 1893
Bobh, W. H. 1214 Louden Ave., Cincinnati. Ohio.	May 16, 1900

BOGART, JOHN Cons. Engr., 29 Broadway, New York, N. Y.	May 18, 1892
BOHMANN, HENRY P. Supt. Water Works, Milwaukee, Wis.	June 24, 1918
BOLLING, CHARLES E. City Engineer, Richmond, Va.	Apr. 15, 1891
BOOKER, WARREN H. c/o State Bd. of Health, Raleigh, N. C.	June 4, 1912
BOOTH, L. M. Prest. Booth Chemical Co., P. O. Box 203, Elizabeth, N. J.	May 12, 1914
BOOTH, WILLIAM MILLER Chem. Engr., Dillaye Bldg., Syracuse, N. Y.	June 8, 1909
BORDEN, MORO M. 310 Lees Ave., Collingswood, N. J.	June 4, 1912
BOUTELLE, GEORGE K. Treas, Kennebec Water Dist., Waterville, Me.	May 12, 1908
BOWKER, CHARLES L. Supt. Brunswick & Topsham Water Dist., Brunswick, Me.	June 10, 1906
BOWLES, JAMES TEN BROECK Lieut.-Col. San. Corps, Am. Exp. Forces, France	June 8, 1909
BOWNE, WILLIAM E. Eng. in Chge. Pumping Stn., Dept. W. S. G. & E., Bellemore L. I.	May 30, 1916
BOYD, M. M. Supt. Water Works, Spartanburg, S. C.	May 10, 1917
BOYLE, EDWARD CHARLES Genl. Supr. of Filtn., E. I. du Pont de Nemours & Co., City Point, Va.	Apr. 14, 1916
BRADLEY, EDGAR JOSEPH Res. Engr., Millbrook Water Works, Millbrook, S. Australia.	June 24, 1918
BRANDLI, H. E. Treas. & Gen. Mgr. Citizens Gas, Elect. & Heating Co., Mt. Vernon, Ill.	Apr. 21, 1915
BREIDENBACH, E. H. Mgr. & Supt. Owensboro Municipal Elect. & Water Softening & Purifying Plants, Owensboro, Ky.	June 24, 1912
BREITZKE, CHARLES F. San. Engr., Jersey City Water Wks., Boonton, N. J.	June 10, 1911
BRENNAN, B. C. Capt. Engr. Corps, Am. Exp. Forces, France	June 24, 1918

BRICKER, R. P. Prest. Shelby Water Co., Shelby, Ohio.	Nov. 23, 1915
BRIGHTMAN, HORACE I. Prest. Staten Island Water Supply Co., 115 Broadway, New York, N. Y.	June 11, 1902
BRITTON, GUY, C.E. 150 Nassau St., New York, N. Y.	Dec. 1, 1913
BROOKS, JAMES E. Prest. James E. Brooks Co., Supt. Water Dept., Glen Ridge, N. J.	Oct. 16, 1914
BROOKS, JOHN N., C.E. Douglaston, N. Y.	June 24, 1913
BROSSMANN, CHARLES Cons. Engr., 1616 Merchants Bk. Bldg., Indianapolis, Ind.	Apr. 4, 1916
BROWER, IRVING C. Comnr. of Pub. Wks., Evanston, Ill.	Aug. 24, 1915
BROWN, C. ARTHUR San. Eng., West Erie Ave., R. F. D. 2, Lorain, O.	June 27, 1905
BROWN, C. D. Mgr. Walkerville Water Co., Walkerville, Ontario.	Oct. 16, 1916
BROWN, CALVIN S. The Belvedere, Toledo, Ohio.	Mch. 15, 1882
BROWN, CHARLES CARROLL Cons. Engr., 304 E. Walnut St., Bloomington, Ill.	May 12, 1906
BROWN, HORACE A., C.E. City Engr. & Supt. Water Wks., Ottumwa, Iowa.	June 10, 1911
BROWN, RASSELAS W. Co A, 112th U. S. Inf., Camp Hancock, Ga.	Apr. 4, 1916
BROWN, ROBERT H. Capt. San. Corps, N. A., Camp A. A. Humphreys, Va.	May 12, 1908
BROWN, WALTER I. City Hall, Bangor, Me.	Oct. 31, 1914
BRUA, E. G. Drawer F, Bartlesville, Okla.	May 12, 1908
BRUCE, T. E. Supt. Water Co., Tupper Lake, N. Y.	Apr. 3, 1917
BRUSH, WILLIAM W. Depty. Ch. Engr., Dept. W. S., G. & E., Municipal Bldg., New York, N. Y.	June 10, 1911
BRYSON, G. H., C.E. Brockville, Ont., Canada.	July 18, 1907

BUCK, WILLIAM H. Mch. 2, 1916
Engr. & Supt. Constr., Riverton & Palmyra Water Co., Riverton, N. J.

BUDELMAN, GEORGE A. Mch. 28, 1914
Asst. Engr., Whitney Ave., Elmhurst, L. I., N. Y.

BUERGER, CHARLES B., C.E. Mch. 28, 1914
c/o Atlantic Refining Co., Philadelphia, Pa.

BULKELEY, OSCAR E. June 24, 1913
Power Dept. Dn Pont Eng. Co., Nashville, Tenn.

BULL, IRVING C. June 8, 1906
Analytical & Cons. Chem., 100 Maiden Lane, New York, N. Y.

BUNKER, GEORGE CYRUS July 10. 1906
Balboa Heights, C. Z.

BUNTING, P. G. Feb. 8, 1916
Mgr. City Pt. Water Co., Box 11, Petersburg, Va.

BURDICK, CHARLES B. July 18, 1907
Hyd. & San. Engr., 1417 Hartford Bldg., Chicago, Ill.

BURGESS, PHILIP June 10, 1911
Hyd. Engr., 828 Columbus Sav. & Trust Bldg., Columbus, Ohio.

BURNETT, M. Apr. 17, 1889
Supt. Water Works, Paducah, Ky.

BURNIE, ARTHUR N. Mch. 27, 1916
Asst. Supt. Biddeford & Saco Water Co., Biddeford, Me.

BURNS, CLINTON S. April 27, 1910
Cons. Hyd. Engr., 402 Interstate Bldg., Kansas City, Mo.

BURNS, T. W. June 27, 1905
City Engr. & Supt. Water Works, Fairbury, Ill.

BUSWELL, A. M. May 10, 1916
Lieut. San. Div. Med. Corps, Am. Exp. Forces, France.

BUTLER, JAMES S. June 10, 1911
Supt. Pub. Serv. Comn., Yazoo City, Miss.

BUTTENHEIM, HAROLD S. June 24, 1913
Ed. *The American City*, 154 Nassau St., New York, N. Y.

BUZZELL, ROYAL S. June 27, 1917
Chem., Supt. Filtn., 726 East Court St., Flint, Mich.

CAIRD, JAMES M. May 16, 1900
Chemist & Bact., 271 River St., Troy, N. Y.

Caldwell, James H., C.E. July 10, 1906
55 First St., Troy, N. Y.

Calkins, Willis N. June 11, 1902
2200 Harriet Ave., Minneapolis, Minn.

Calvo, Arturo R. Apr. 14, 1916
Mgr. of Sales, The Permutit Co., 440 Fourth Ave., New York, N. Y.

Cameron, Archibald Preston June 4, 1912
10 Clive St., Calcutta, India.

Campbell, C. B. May 4, 1915
Supt. Bureau of Water, Altoona, Pa.

Campbell, George A. June 24, 1913
P. O. Box 805, Reno, Nev.

Cappelen, F. W. Sept. 7, 1893
City Engr., 2129 Girard Ave., Minneapolis, Minn.

Carlin, Philip Apr. 15, 1891
Supt. Water Works, Sioux City, Iowa.

Carlisle, Charles C. Apr. 27, 1910
Cons. Engr., 212 First Natl. Bk. Bldg., Cheyenne, Wyo.

Carr, J. A. May 3, 1916
Corp. Aviation Sect., Signal Corps, Amer. Exp. Forces, France.

Carroll, Eugene June 7, 1904
V.-Prest. & Mgr. Water Wks., Butte, Mont.

Carstein, Lorenz W. F. May 8, 1915
Supt. Long Beach Water Co., Long Beach, N. Y.

Carter, C. D. July 10, 1906
Supt. Water & Sewage Dept., Charlottesville, Va.

Case, R. E. June 9, 1916
Ensign Naval Reserve, New London, Conn.

Castle, George J. Nov. 24, 1914
Supt. & Secty., Carlinville Wtr. Sup. Co., Carlinville, Ill.

Caston, D. L. June 8, 1916
Supt. Water Works, Commerce, Ga.

Catchpole, C. T. June 10, 1911
Asst. Genl. Mgr. The Denver Union Water Co., P.O. Box 629, Denver, Colo.

Catlett, George F. June 8, 1916
Capt. San. Corps, Am. Exp. Forces, France

Cavallier, C., C.E. — Nov. 1, 1916
62 Rue Coumartin, Paris, France.

Chamot, E. M. — Apr. 19, 1915
Prof. San. Chemistry, Cornell University, Ithaca, N. Y.

Champe, George, C.E. — June 24, 1913
610 Nasby Bldg., Toledo, Ohio.

Champion, R. B. — Mch. 28, 1914
Box 67, Chester, Pa.

Chapman, L. H. — June 26, 1918
Comnr. Water & Light, Kansas City, Kans.

Chase, Charles P., C. E. — Sept. 12, 1916
123 Sixth Ave., Clinton, Ia.

Cheney, J. Y. — May 1, 1917
2nd Lieut. Co. D., 17th Inf., Tampa, Fla.

Chester, Charles E., C.E. — Dec. 18, 1913
Mgr. City Water Co., Shelbyville, Ill.

Chester, J. N., H.& M.E. — June 10, 1911
Union Bk. Bldg., Pittsburgh, Pa.

Childs, J. A. — Feb. 24, 1917
Engr. State Bd. of Health, 1988 Summit Ave., St. Paul, Minn.

Chipley, Dudley — Apr. 15, 1917
Engr. & Supt. Columbus Water Wks., P. O. Box 854, Columbus, Ga.

Chipman, Willis, C.E. — April 18, 1888
103 Bay St., Toronto, Ont., Canada.

Chisham, J. M. — June 11, 1902
Supt. Water Co., Atchison, Kan.

Christie, J. G. C., C.E. — Nov. 10, 1914
Lieut. 505 Aero Squadron, Camp Greene, Charlotte, N. C.

Claiborne, Herbert A. — May 10, 1917
Lieut. 485th Aero. Squad. Am. Exp. Forces.

Clancy, Lester J. — May 9, 1915
Supt. Stge. Yd., Bd. of Water Comnrs., 729 Canton Ave., Detroit, Mich.

Clark, H. W. — May 29, 1895
Pres. & Gen. Mgr. Clear Water Co., Mattoon, Ill.

Clark, Richard — June 27, 1905
Supt. Water Wks., Merritton, Ont.

Clark, William H. June 1, 1917
Supt. Water Wks., Avon, N. Y.

Clarke, David Dexter, Nov. 1, 1914
Ch. Engr. Bur. of Water Wks., Portland, Ore.

Clayton, R. M. Apr. 15, 1891
Cons. Engr., 112 Hurt St., Atlanta, Ga.

Clemmitt, Robert L. Apr. 27, 1910
3625 Springdale Ave., Baltimore, Md.

Cleverdon, Walter S. L. Apr. 4, 1916
Asst. Engr., Dept. W. S. G. & E., 2323 Loring Place, Bronx, New York, N. Y.

Clifton, Charles Elmer Apr. 27, 1910
Chemist, 271 River St., Troy, N. Y.

Clinkenbeard, John F. Oct. 23, 1917
Water Com., Missouri Valley, Ia.

Cobb, Charles H. June 7, 1904
Supt. Water Wks., Kankakee, Ill.

Cobleigh, W. M. Dec. 29, 1913
Prof. of Chemistry, Montana State College, Bozeman, Mont.

Coggeshall, R. C. P. Dec. 30, 1914
Supt. Water Wks., New Bedford, Mass.

Cole, Edward S. June 11, 1902
Prest. The Pitometer Co., 25 Elm St., New York, N. Y.

Colehour, R. A. June 24, 1913
Asst. Water Engr., 3517 Du Pont Ave., South, Minneapolis, Minn.

Collins, F. W. May 19, 1916
Supt. Water Wks., Box 258, Manistee, Mich.

Conant, E. R. May 1, 1917
Ch. Engr., City of Savannah, Savannah, Ga.

Conard, W. R. June 7, 1904
Sav. Inst. Bldg., Burlington, N. J.

Connor, F. J. May 16, 1900
Supt. Water Wks., Sioux Falls, S. Dak.

Connor, Virgil R. May 12, 1908
Trustee Kennebec Water Dist., Fairfield, Me.

Conrad, L. E. May 14, 1915
Prof. Civil & Highway Engrg., 317 N. 17th St., Manhattan, Kans.

CONVERSE, WILLIAM A. — June 8, 1909
Chemist, McCormick Bldg., Chicago, Ill.

CONWAY, G. R. G. — June 8, 1909
The Mexican Lt. & Power Co., 18 Manning Arcade, Toronto, Ont., Can.

COOK, HORACE J., C.E. — Feb. 11, 1917
Asst. Engr. Kennebec Water Dist., 14 Burleigh St., Waterville, Me.

COOK, JOHN H. — July 10, 1906
Hyd. Engr. East Jersey Water Co., 158 Ellison St., Paterson, N. J.

COOPER, GEORGE F. — May 12, 1914
Secty. & Treas. Water Works, Xenia, Ohio.

COOPER, SAMUEL W. — May 12, 1914
C. & Hyd. Engr., Lewistown, Pa.

COPPOCK, WILLIAM — June 24, 1913
Board of Trustees, Council Bluffs, Iowa.

CORBIN, CLEMENT K. — May 12, 1908
Prest. Bergen Water Co., 243 Washington St., Jersey City, N. J.

CORBIN, H. K. — Apr. 16, 1914
Contractor, 30 Church St., New York, N. Y.

CORIN, MAGNUS F. — Apr. 27, 1910
Chemist, 511 Hansberry St., Germantown, Pa.

CORR, ANDREW S. — June 27, 1905
Inspector, 350 Thomas St., Phillipsburg, N. J.

COSCULLUELA, JUAN ANTONIO — June 24, 1913
Calle de Obispo 54, Havana, Cuba.

COTHRAN, THOMAS W., C.E. — June 4, 1913
114 Blake St., Greenwood, S. C.

COULT, F. H. — Oct. 23, 1914
Cons. Engr., 5112 Raymond Ave., St., Louis, Mo.

COULTER, WALDO S. — Dec. 6, 1916
Cons. Engr., 114 Liberty St., New York, N. Y.

COWAN, JOHN D. — Apr. 14, 1916
City Water Comnr., Waukon, Iowa.

COX, HOMER F. — May 12, 1914
Ch. Engr. Scranton Gas & Water Co., 430 Colfax Ave., Scranton, Pa.

COXE, WILLIAM G. — Apr. 14, 1916
Water Comnr., 1005 Broome St., Wilmington, Del.

CRAMER, W. S. May 12, 1908
Chf. Engr., Water Wks. Co., P. O. Box 42, Lexington, Ky.

CRANE, HON. ARTHUR M. May 7, 1918
Mayor, Roselle Park, N. J.

CRANE, JACOB L., JR. Nov 12, 1917
San. Engr., 204 Locust St., Harrisburg, Pa.

CRICHTON, ANDREW B. Apr. 21, 1915
Secty. & Treas. Portage Water Co., Johnstown, Pa.

CRIPPS, GEORGE E. June 8, 1909
Supt. Water Works Repair Dept., 18 Eagle St., Rochester, N. Y.

CROLL, EMIL A. Sept. 7, 1893
Supt. Water Wks., Iron Mountain, Mich.

CROXEN, C. A. Feb. 5, 1916
Supt. Taxpayers Municipal Water Works, 105 E. Montgomery St., Creston, Iowa.

CROZIER, RAY Apr. 21, 1915
Engr. & Supt. Peoria Water Wks., Peoria, Ill.

CUDDEBACK, ALLAN W. June 7, 1904
Engr. & Supt. Passaic Water Co., 158 Ellison St., Paterson, N. J.

CULYER, THURSTON C. June 26, 1916
Engr. Eastern Watershed Div., Dept. W. S. G. & E., City of N. Y., Purdy Station, N. Y.

CUMMIN, GAYLORD C., C.E. June 4, 1912
City Mgr., Grand Rapids, Mich.

CURRAN, H. C. May 12, 1914
Supt. Water Works, Waterford, N. Y.

CUTTS, FRANCIS T. June 15, 1914
Asst. Water Comnr., 34 East Grand Ave., St. Louis, Mo.

DAGGETT, FRED W. Jan. 28, 1916
Supt. Filtn. Plant, Trenton, N. J.

DAILY, CORNELIUS M. Apr. 15, 1918
Engr. in Chge. Sup. & Purif. Sect. St. Louis Water Dept., St. Louis, Mo.

DALLYN, F. A., C.E. Dec. 18, 1913
Prov. San. Engr., 137 Geoffrey St., Toronto, Ont.

DANIELS, FRANCIS E. Sept. 18, 1918
Capt. San. Corps, Camp Lee, Petersburg, Va.

DAPPERT, JAMES W., C.E. Oct. 23, 1914
Lock Box 141, Taylorville, Ill.

DAVIDSON, GEORGE M. Chem. & Engr. of Tests, C. & N. W. Ry. Shops, Chicago, Ill.	Apr. 19, 1915
DAVIS, CARLETON E. Chief, Bureau of Water, Philadelphia, Pa.	June 24, 1918
DAVIS, E. E. Supt. Water Works Dept., Richmond, Va.	May 12, 1908
DAVIS, FRANK J. Supt. Ansonia Water Co., 100 Main St., Ansonia, Conn.	May 13, 1916
DAVISSON, W. C. V.-Prest. & Treas., W. Va. Water & Electric Co., Charleston, W. Va.	June 4, 1912
DAW, LAWRENCE Ch. Engr. Underwriters Assn. of N. Y., 700 Gurney Bldg., Syracuse, N. Y.	May 13, 1916
DAWSON, R. C. Supt. Water Dept., City Hall, Bay City, Mich.	June 8, 1916
DAY, LEONARD A. Ch. Mech. Engr. Op. Sect., Wtr. Dept., 4015-A Greer Ave., St. Louis, Mo.	Apr. 4, 1917
DEBERARD, W. W. Western Ed. *Engineering News-Record*, 1570 Old Colony Bldg., Chicago, Ill.	June 4, 1917
DECKER, A. CLINTON Chem. Bact. & San. Engr., P. O. Box 790, Birmingham, Ala.	June 15, 1915
DECKER, JOHN H. Bartlett Bldg., Atlantic City, N. J.	July 18, 1907
DENMAN, ARTHUR R. Bd. Street & Water Comnrs., 790 Broad St., Newark, N. J.	June 8, 1909
DENMAN, CHARLES SING Genl. Mgr. Des Moines Water Co., Des Moines, Iowa.	Dec. 22, 1915
DENNETT ROBERT C. Hyd. Engr., Natl. Bd. Fire Underwriters, 76 William St., New York, N. Y.	May 12, 1914
DESSERY, FLOYD G. Civil & Hyd. Engr., 511-514 Central Bldg., Los Angeles, Cal.	Apr. 27, 1910
DEVARONA, I. M. 805 St. Nicholas Ave., New York, N. Y.	June 4, 1912
DEWEY, ALVIN H. V.-Prest. & Genl. Mgr. R. & L. O. W. Co., 440 Powers Bldg., Rochester, N. Y.	June 4, 1912

DEVINE, WILLIAM J., C.E. Supt., Ambler Spring Water Co., Ambler, Pa.	July 18, 1907
DILL, H. A. Supt. Water Works, Richmond, Ind.	May 16, 1900
DITTOE, W. H. Ch. Engr. State Dept. of Health, Columbus, Ohio.	Mch. 28, 1914
DIVEN, J. M. Supt. Water Works, Troy. N. Y.	Apr. 16, 1884
DIVEN, J. M., JR., C.E. 2nd Lieut. U. S. O. R., Edgewood Arsenal, Edgewood, Md.	June 4, 1918
DOCKWEILER, JOHN H., C.E. 624–5 Crocker Bldg., San Francisco, Cal.	May 12, 1908
DOMAN, JOSEPH Asst. Engr. State Bd. of Health, 102 C. E. Bldg., Berkeley, Cal.	May 1, 1917
DONAHUE, J. P. Secty. & Treas. Water Co., Davenport, Iowa.	Apr. 16, 1884
DONALDSON, WELLINGTON Amer. Water Wks. & Elect. Co., 50 Broad St., New York, N. Y.	Apr. 27, 1910
DONNAN, ALVAN Secty. Waynesburg Water Co., Washington, Pa.	July 18, 1907
DONNELLY, RICHARD J. San. Engr., 515 West 156th St., New York, N. Y.	May 10, 1917
DORWAY, C. M. Supt. Water Works, Eveleth, Minn.	May 10, 1917
DOTEN, LEONARD S. Major Q. M. C., N. A., Constr. Div., 1714 Euclid St.. N. W., Washington, D. C.	Oct. 23, 1914
DOWNES, JOHN R. Green Brook Park, Bound Brook, N. J.	July 10, 1906
DRAKE, DR. C. ST. CLAIR Secty. State Bd. of Health, Springfield, Ill.	Jan. 15, 1916
DRAKE, CHESTER F. Div. Supt. Pittsburgh Filtn. Plant, Aspinwall, Pa.	Apr. 27, 1910
DRAKE, WILLIAM O. City Engr., Supt. Pub. Wks., City Hall, Corning, N. Y.	May 1, 1917
DREW, JOHN A. Prest. Castle Heights Water Co., 90 West St., New York, N. Y.	May 1, 1917

DUGGAN, THOMAS R., PH.D., F.I.C. Chemists Club, 52 E. 41st St., New York, N. Y.	Dec. 18, 1918
DUMOULIN, W. L. New Cornelia Copper Co., Ajo, Arizona	June 10, 1911
DUNCANSON, ARCHIE VAIL City Engr.'s Office, Minneapolis, Minn.	July 15, 1917
DUNHAM, H. F., C.E. 149 Broadway, New York, N. Y.	Apr. 16, 1884
DUNLAP, FRED C. Cons. Engr., Oak Lane, Philadelphia, Pa.	May 12, 1908
DUNLAP, JOHN H. Asst. Prof. Hyd. & San. Engrg., State Univ. of Iowa, Iowa City, Iowa.	Oct. 23, 1914
DUNWOODY, J. H. Chemist Water Dept., Erie, Pa.	June 24, 1918
DURLAND, SMITH N. Cashier Queens Co. Water Co., 15 John St., Far Rockaway, N. Y.	Jan. 27, 1914
DURST, J. ARTHUR, M.E. 112 N Broad St., Philadelphia, Pa.	May 12, 1914
DUSINBERRE, GEORGE B. Major O. R. C., 7th & B Sts., Washington, D. C.	Nov. 17, 1916
DUTTON, MARSHALL S. E. St. L. & Interurban Water Co., 513 Missouri Ave., East St. Louis, Ill.	Dec. 22, 1915
DWYER, CORNELIUS 18 Chuctanunda St., Amsterdam, N. Y.	Oct. 16, 1914
EARL, GEORGE GOODELL Gen. Sup. Sewerage & Water Bd., 502 City Hall Annex, New Orleans, La.	July 18, 1907
EARL, RALPH Hyd. Engr., c/o Chas. W. Tarr, 110 Henry St., Detroit, Mich.	June 13, 1916
EASTERLING, R. A. Supt. Elect. Lt. & Water Wks, Union, S. C.	Mch 28, 1914
EASTWOOD, JOHN THOMPSON Prin. Asst. Engr. Sewer & Water Bd., City Hall Annex, New Orleans, La.	June 8, 1909
EDWARDS, WILLIAM R. Asst. Supt. Passaic Water Co., 156 Ellison St., Paterson, N. J.	Apr. 16, 1914
EGLOF, JOHN HENRY, C.E. 2216 13th St., Troy, N. Y.	June 4, 1912

Eldredge, Guy Chem. Supt. of Filtn., 920 Fournier St., Ft. Worth, Tex.	Dec. 29, 1913
Eldridge, H. D. Treas. Princeton Water Wks., Princeton, N. J.	Apr. 14, 1916
Elliott, G. A. Engr. Spring Valley Water Co., 1270 Sacramento St., San Francisco, Cal.	May 14, 1915
Elliott, Robert Water Comnr., Nashville, Tenn.	Apr. 22, 1914
Ellis, George R. 11 South LaSalle St., Chicago, Ill.	July 18, 1907
Ellsworth, Harry Supt. Water & Lt. Dept., Meadville, Pa.	July 18, 1907
Elrod, Henry E. Cons. Engr., Interurban Bldg., Dallas, Tex.	Mch. 1, 1916
Ely, Howard M. Supt. Water Co., Danville, Ill.	June 8, 1909
Emerson, C. A., Jr. Act. Ch. Engr., State Dept. of Health, Harrisburg, Pa.	May 12, 1908
Enger, M. L. Asst. Prof. Theoret. & App. Mech., Univ. of Illinois, Urbana, Ill.	Apr. 23, 1915
Engh, Harry Marius Civil & Appraisal Engr., American Appraisal Co., Milwaukee, Wis.	Mch. 27, 1916
England, R. G., C.E. Fargo Engineering Co., 304 Commonwealth Bldg., Jackson, Mich.	Sept. 19, 1914
Engle, S. G. City Chemist, 664 Connecticut St., Gary, Ind.	Nov. 10, 1914
Eno, F. H., C.E. Ohio State Univ., Columbus, Ohio.	Dec. 1, 1913
Enslow, Linn Harrison Chem. Filter Plant, Spartanburg, S. C.	Aug. 12, 1918
Ericson, John E. 848 Lakeside Place, Chicago, Ill.	June 7, 1887
Ervast, Andrew, C.E. Union Bldg., San Diego, Cal.	May 12, 1908
Etnyre, S. L. Supt. Water Works, Council Bluffs, Ia.	May 14, 1915

ETZEL, GEORGE C. Analyst, 1101 12th Ave., Rock Island, Ill.	June 8, 1916
EVERETT, CHESTER M. of Hazen, Whipple & Fuller, 30 E. 42d St., New York, N. Y.	Mch. 14, 1915
EVERETTE, DR. WILLIS EUGENE Cons. Techn., 3512 S. Eleventh St., Tacoma, Wash.	Jan. 5, 1914
EVINGER, M. I. 211 Securities Building, Des Moines, Iowa.	Apr. 27, 1910
EWING, JAMES Hunter Dist. Water Sup. & Sew. Bd., Newcastle, N. S. W., Australia.	June 24, 1913
EYMER, HERMAN H. City Engineer, Saginaw, Mich.	June 4, 1912
FALLER, C. Supt. Carlisle Gas & Water Co., Carlisle, Penn.	June 8, 1909
FARNSWORTH, S. A. Comnr. of Finance, City Hall, St. Paul, Minn.	June 26, 1918
FELIX, GEORGE H. 138 N. Ninth Street, Reading, Pa.	Sept. 7, 1893
FELLOWS, C. L. Water Wks. Engr., 39 Lowther Ave., Toronto, Can.	June 7, 1904
FEREBEE, JAMES L. Sew. Comn., City Hall, Milwaukee, Wis.	Sept. 19, 1914
FERGUSON, HARRY FOSTER 1st Lieut. E. R. C., A. S., S. O. S., Am. Exp. Forces	Nov. 10, 1914
FERGUSON, S. F. Cons. Engr., 100 William St., New York, N. Y.	Jan. 12, 1915
FILBERT, WILLIAM D. Womelsdorf Consol. Water Co., Womelsdorf, Pa.	Apr. 27, 1910
FINKLE, F. C. Cons. Hyd. Engr., 449 I. W. Hellman Bldg., Los Angeles, Cal.	June 24, 1912
FISCHER, CHARLES H. Fire Protection Engr., 2844 Hudson Blvd., Jersey City, N. J.	June 27, 1914
FISHER, E. A. Cons. Engr., Rochester, N. Y.	June 4, 1912
FISHER, E. P. Supt. London Water Wks. Co., London, Ohio.	May 14, 1915
FISHER, L. A. P. O. Box 198, Concord, N. C.	Jan. 27, 1914

FITHIAN, FRANK S. — Feb. 8, 1916
Ch. Clerk Water Dept., City Hall, Camden, N. J.

FITZPATRICK, JAMES R., C.E. — June 27, 1905
Gen. Mgr. Grand Rapids Hydraulic Co., Grand Rapids, Mich.

FLAA, INGWALD E. — May 14, 1915
Asst. Engr. Spring Valley Water Co., 375 Sutter St., San Francisco, Cal.

FLAD, EDWARD — July 23, 1916
Pub. Serv. Comn., Jefferson City, Mo.

FLANAGAN, JOHN C. — June 24, 1913
Secty. Bd. of Water Comnrs., St. Paul, Minn.

FLATLEY, JAMES P. — June 8, 1909
Supt. Water Co., Green Bay, Wis.

FLEMING, VIRGIL R. — Apr. 14, 1915
204 Lab. App. Mech., Urbana, Ill.

FLINN, ALFRED DOUGLAS — Mch. 1, 1916
Secty. United Eng. Soc., 901 Eng. Soc. Bldg., New York, N. Y.

FOERSTERLING, DR. HANS — June 12, 1916
The Abor Farm, Jamesburg, N. J.

FOLWELL, A. PRESCOTT — July 10, 1906
Ed. *Municipal Journal*, 243 West 39th St., New York, N. Y.

FOSS, W. E. — July 10, 1906
Ch. Engr. Metropolitan Water Wks., 1 Ashburton Place, Boston, Mass.

FOUSHEE, J. G. — Apr. 30, 1917
Comnr. of Pub. Works, Greensboro, N. C.

FOWLER, ARTHUR G. — Apr. 27, 1910
Supt. Water Works., R. F. D. No. 3, Cumberland, Md.

FOWLER, EDWARD A. — Apr. 27, 1910
Asst. Engr. Sew. & Water Bd., City Hall Annex, New Orleans, La.

FOX, CHARLES L. — June 4, 1912
Asst. Supt. Penna. Water Co., 712 South Ave., Wilkinsburg, Pa.

FRANCIS, WALTER J. — Apr. 4, 1916
Cons. Engr., 260 St. James St., Montreal, Can.

FRANK, FRED W. — July 18, 1907
Secty. & Mgr., Water Wks., Brantford, Ont., Can.

FREDRICK, W. DAYTON — May 12, 1914
Bridgeton Water Works, Bridgeton, N. J.

FREILING, HENRY J. Asst. Supt. Water Works, Hannibal, Mo.	May 12, 1914
FRENCH, D. W. Supt. Hackensack Water Co., P.O. Box 98, Weehawken, N. J.	May 29, 1895
FRENCH, DUDLEY K. Chem., Dearborn Chemical Co., 2005 McCormick Bldg., Chicago, Ill.	Feb. 25, 1914
FRENCH, E. V., M.E. 31 Milk St., Boston, Mass.	July 10, 1906
FRITZE, L. A. 1st Lieut. Field Laboratory 42nd Div. Rainbow, Am. Exp. Forces, France.	Jan. 15, 1916
FUERTES, JAMES H. Cons. Engr., 140 Nassau St., New York, N. Y.	July 10, 1906
FULLER, FRANK L., C.E. 12 Pearl St., Boston, Mass.	July 10, 1906
FULLER, GEORGE W. Cons. Engr., 170 Broadway, New York, N. Y.	June 15, 1898
FULLER, W. A. Cons. Engr., 1415 Chemical Bldg., St. Louis, Mo.	Oct. 14, 1914
FULTON, D. F. City Engr., City Hall, Yonkers, N. Y.	May 15, 1915
GABY, FREDERICK A. Ch. Engr., Hydro-Electric Power Co., of Ont., 190 University Ave., Toronto, Ont., Can.	Feb. 8, 1916
GADFIELD, C. E. Supt. Bd. of Pub. Affairs, Wellington, Ohio.	June 8, 1916
GALLAGHER, H. A. Mgr. Water Co., Independence, Mo.	June 8, 1909
GARMAN, H. O. Ch. Engr. Ind. Pub. Util. Comn., 2062 N. Meridian St., Indianapolis, Ind.	May 30, 1916
GATES, H. V. Prest. Hillsboro Power & Invest. Co., Hillsboro, Ore.	June 7, 1904
GAUB, JOHN Chem. Engr. Filtn. Plant, Washington, D. C.	Oct. 13, 1913
GAVETT, WESTON 1st Lieut. S. C., Comdg. San. Squad No. 1, 28th Div., Camp Hancock, Ga.	Nov. 10, 1914
GAYNOR, KEYES C. Cons. Engr., 405–6 Frances Building, Sioux City, Ia.	May 7, 1917

Gear, Patrick Supt. Water Dept., Holyoke, Mass.	June 24, 1913
Gelston, W. R. Supt. Water Wks. Quincy, Ill.	July 18, 1907
Gerber, Winfred D. Civil & San. Engr., 1611 Fargo Ave., Chicago, Ill.	Apr. 19, 1915
Gettings, M. T. Supt. Water Works, Monroe, Wis.	June 8, 1904
Giclas, Eli Ch. Engr., Ariz. Lumber & Timber Co. Flagstaff, Ariz.	June 27, 1905
Gideon, Abraham, C.E. Ch. Engr., Sewer & Water Wks. Constr., Manila, P. I.	June 8, 1909
Gilchrist, Charles B. Asst. Supt. Water Wks., Newburgh, N. Y.	May 12, 1914
Gillespie, C. G. Ch. Engr., San. Engrg. Dept. State Bd. Health, C. E. Bldg., Berkeley, Cal.	June 10, 1911
Gilman, Charles Edward Cons. Hyd. Engr., 851 Calmar Ave., Oakland, Cal.	June 4, 1912
Gochnauer, Harry W. San. Engr., Box 31, Port Edwards, Wis.	Nov. 1, 1916
Goentner, William B. Supt. McCabe Chemical Co., Charlotte, N. C.	June 8, 1909
Goldsmith, Clarence Major Q. M. C., N. A.. Constr. Div., 7th & B Sts., Washington, D. C.	Dec. 27, 1915
Goodell, J. M., H.E. 106 Loraine Ave., Upper Montclair, N. J.	Apr. 27, 1885
Goodrick, E. H. Supt. Water Wks., Fredericksburg, Va.	May 5, 1917
Gordon, T. C. Secty-Treas., Gen. Mgr. Water Wks., Little Falls, Minn.	Jan. 28, 1916
Gore, William Cons. Engr., John ver Mehr Engrg. Co., 154 Simcoe St., Toronto, Ont.	May 30, 1916
Goss, M. N. Comnr. Pub. Wks., City Hall, St. Paul, Minn.	June 26, 1918
Goudey, Ray F. San. Engr., 2529 Hilgard Ave., Berkeley, Cal.	Apr. 30, 1918

Gould, J. W. DuB. — Oct. 16, 1914
30 Church St., New York, N. Y.

Graf, August V. — June 15, 1914
Ch. Chem., St. Louis Water Wks., 34 East Grand Ave., St. Louis, Mo.

Graff, George W. — Dec. 22, 1916
40th Co., 10th Tr. Btn., Camp Lee, Va.

Graham, James W. — June 4, 1912
16 Casco St., Portland, Me.

Grantham, C. M. — June 1, 1916
Supt. Water Dept., Goldsboro, N. C.

Grasty, E. C. — June 1, 1916
Owner and Mgr. Water, Elect. Lt. & Tel. Co., Winkelman, Ariz.

Gray, Percy — Dec 31, 1917
Mgr. Pumping Plant, Jefferson, Ia.

Grayson, Theodore J. — June 23, 1917
Prest. N. J. Water Serv. Co., 1327 Real Est. Trust Bldg., Philadelphia, Pa.

Greeley, Samuel A. — July 18, 1907
Winnetka, Ill.

Green, F. W. — Dec. 22, 1915
Supt. Filtn. & Pumping, Montclair Water Co., Little Falls, N. J.

Green, Frederick — May 12, 1914
Supt. Commonwealth Water & Lt. Co., 47 Mountain Ave., Summit, N. J.

Green, Paul Evans — Apr. 14, 1915
Civil & San. Engr., 17 N. LaSalle St., Chicago, Ill.

Greenalch, Wallace — July 18, 1917
Comnr. Pub. Wks., Albany, N. Y.

Gregory, John Herbert — July 10, 1906
Cons. Hyd. Engr. & San. Expert, 170 Broadway, New York, N. Y.

Grieve, Thomas — Apr. 16, 1914
88 Market St., Perth Amboy, N. J.

Griffin, J. William — May 10, 1917
Supt. Water Dept., 121 Garrison Ave., Jersey City, N. J.

Griswold, F. M. — July 18, 1907
Ins. Engr., 56 Cedar St., New York, N. Y.

Gobelman, Fred. J. — June 7, 1897
47 W. 34th St., New York, N. Y.

Gushee, Edward G. — May 12, 1908
2d Asst. Engr. Bur. of Water, 2122 N. 28th St., Philadelphia, Pa.

Gwinn, Dow R. — Sept. 7, 1893
Prest. Water Co., Terre Haute, Ind.

Habermeyer, George Conrad — Apr. 14, 1915
Civil & San. Engr., 1011 W. Clark St., Urbana, Ill.

Hadden, S. C. — June 4, 1912
Ed. *Municipal Engineering*, 538 S. Clark St., Chicago, Ill.

Hale, Dr. Frank E. — May 12, 1908
Dir. of Lab., Mt. Prospect Laboratory, Brooklyn, N. Y.

Hale, Richard King, C.E. — June 10, 1911
Lieut.-Col 101 F. A., Am. Exp. Forces.

Hall, Albert S. — May 16, 1900
Supt. Kennebec Water Dist., Waterville, Me.

Hall, Harry R. — May 8, 1915
Asst. Ch. Engr. State Dept. of Health, 16 W. Saratoga St., Baltimore, Md.

Hall, J. W. — June 7, 1906
Mgr., San Joaquin Dist., Water Dept. Pacific Gas & Elect. Co., Stockton, Cal.

Halpin, George R. — June 13, 1916
515-7th Ave., Watervliet, N. Y.

Halpin, Thomas F. — July 18, 1907
A. P. Smith Mfg. Company, East Orange, N. J.

Hammer, Edwin W. — May 12, 1914
Cons. Engr., 160 Broadway, New York, N. Y.

Hammond, W. H. — June 24, 1914
Supt. Lindsay Water Wks., Lindsay, Ont., Can.

Handy, James Otis — May 8, 1915
Dir. Pittsburg Testing Lab., 612–620 Grant St., Pittsburgh, Pa.

Hansen, A. E. — Jan. 1, 1918
Hyd. & San. Engr., 2 Rector St.. New York, N. Y.

Hansen, Paul — June 4, 1912
Capt. U. S. Engrs Genl. Hdqtrs., Am. Exp. Force.

Hapgood, Lyman P. — June 8, 1909
Supt. Dept. of Water & Lt., Box 253, Jamestown, N. Y.

HARDGRAVE, A. Civ. & Elec. Engr., 1301 Southwestern Life Bldg., Dallas, Tex.	June 15, 1914
HARDING, C. T. Supt. Water and Lt. Dept., 516 Chestnut St., Virginia, Minn.	Feb. 27, 1917
HARDING, GEORGE Mgr., 1105 Paulsen Bldg., Spokane, Wash.	June 24, 1913
HARDING, JOHN H. Supt. Water Works, La Porte, Ind.	June 26, 1918
HARDING, ROBERT J. V.-Prest. San Antonio Water Supply Co., 106 Market St., San Antonio, Texas.	Oct. 23, 1914
HARDY, EDWARD DANA Supt. Aqueduct & Filtn. Plant, Washington, D. C.	May 12, 1908
HARGREAVES, JOHN Govt. Hyd. Engr., Water Supply Dept., Brisbane, Queensland, Australia.	June 8, 1916
HARMAN, JACOB A. Cons. Engr., 144 Fredonia Ave., Peoria, Ill.	Apr. 11, 1917
HARPER, L. V. Mgr. Chelan Electric Co., Chelan, Wash.	Aug. 19, 1914
HARRIS, H. M. Supt. Water Works, Jackson, Tenn.	May 13, 1916
HARRIS, R. C. Comnr. of Wks., City Hall, Toronto, Ont., Can.	May 12, 1914
HARRISON, JOHN H. Kingston Water Dept., Kingston, N. Y.	Apr. 16, 1914
HARRUB, C. NELSON San. Engr., 1437 Spearing St., Jacksonville, Fla.	Dec. 30, 1914
HASKINS, C. A. Capt. San. Corps, N. A., Washington, D. C.	June 25, 1914
HATCH, EDWARD L. Gen. Mgr. Stamford Water Co., Stamford, Conn.	July 10, 1906
HATFIELD WILLIAM DURRELL Asst. Chem., State Water Survey, Urbana, Ill.	Feb 2, 1917
HATTON, T. CHALKLEY Ch. Engr., City Hall, Milwaukee, Wis.	June 11, 1902
HATTON, WILLIAM J. 211 Ogden Ave., Escanaba, Mich.	May 12, 1908
HAUSER, STEPHEN J. Chem. & Bact., 1669 Cedar Ave., College Hill, Cincinnati, Ohio.	May 14, 1915

HAWKINS, H. C. — Dec. 22, 1915
City Engr., Oskaloosa, Ia.

HAWLEY, W. C. — Apr. 27, 1910
Ch. Engr. & Gen. Supt. Penna. Water Co., 712 South Ave., Wilkinsburg, Pa.

HAYFORD, B. B. — June 8, 1909
Supt. Water Wks., Waukesha, Wis.

HAZEN, ALLEN, C. E. — May 27, 1896
42d St. Bldg, New York, N. Y.

HAZLEHURST, GEORGE H. — Nov. 1, 1914
State Bd. of Hlth., Montgomery, Ala.

HAZLEHURST, J. N. — July 10, 1906
Major Eng. U. S. R., Genl. Hdqtrs., Am. Exp. Forces

HEARD, ALBERT — July 18, 1907
Supt. and Treas., Hagerstown, Md.

HECHT, J. L. — June 10, 1911
Mech. Engr., Pub. Serv. Co., 72 West Adams St., Chicago, Ill.

HEERMANS, H. C. — June 26, 1886
Mgr. Water Wks. Co., Hoquiam, Wash.

HEFFELFINGER, J. MILTON — Mch. 18, 1918
622 Hecla St., Ironton, O.

HELLER, F. P. — May 12, 1908
Water Comnr., 236 Penn St., Reading Pa.

HENBY, WILLIAM H. — May 14, 1915
Secty. & Mgr. West St. Louis Water & Lt. Co., 6600 Delmar Ave., St. Louis, Mo.

HENDERSON, CHARLES R. — June 18, 1901
Mgr. Davenport Water Co., Davenport, Iowa.

HENDERSON, JOHN BAILLIE, C.E. — Sept. 27, 1915
"Sun" Fdry., Wickham St., Brisbane, Queensland, Australia.

HENDRICK, WALLACE M. — May 14, 1915
1st Lieut. Engrs. U. S. R. 301st, Am. Exp. Forces

HENRY, EDWARD WILLIAM — May 12, 1908
Supt. Meter Dept., 450 Fairmont Ave., Jersey City, N. J.

HERING, RUDOLPH — July 14, 1887
Cons. Hyd. & San. Engr., 170 Broadway, New York, N. Y.

HERR, J. O. — June 8, 1916
Supt. Atlantic Co. Water Co. of N. J., 232 N. Main St., Pleasantville, N. J.

HERSEY, FRANCIS C., JR. Secty. Water & Municipal Lt. Comnrs., Wellesley, Mass.	July 18, 1907
HETZER, MENTOR Mgr. Moundsville Water Co., Moundsville, W. Va.	Dec. 22, 1916
HEYDRICH, A. Prest. Matanzas Water Wks., Matanzas, Cuba.	July 18, 1907
HICKS, J. S. Supt. Water Co., Berwick, Pa.	June 10, 1911
HIGGINS, LAFAYETTE, C.E. San. Engr. State Bd. of Health, 1144 W. 25th St., Des Moines, Ia.	Dec. 22, 1915
HIGHLAND, SCOTLAND G. Secty., Treas. & Gen. Mgr., Clarksburg Water Bd., Clarksburg, W. Va.	June 24, 1913
HILL, ALBERT B. Cons. Eng., 100 Crown St., New Haven, Conn.	Oct. 26, 1914
HILL, JOHN W. Cons. Engr., 406 First Natl. Bk. Bldg., Cincinnati, Ohio	June 26, 1886
HILL, NICHOLAS S., JR. Cons. Engr., 100 William St., New York, N. Y.	June 18, 1901
HILLES, T. ALLEN Water Comnr., 1600 West Seventh St., Wilmington, Del.	June 24, 1913
HILSCHER, RALPH State Bd. of Health, 210 Union League Bldg., Los Angeles, Cal.	Nov. 1, 1914
HINKLEY, ROBERT L. Insp. Factory Ins. Ass'n, Hartford, Conn.	May 12, 1908
HINMAN, JACK J., JR. 1st Lieut., S. C. N. A., Army Medical School, Washington, D. C.	Apr. 21, 1915
HOAD, WILLIAM CHRISTIAN Prof. San. Engrg., Univ. of Michigan, Ann Arbor, Mich.	June 24, 1913
HOAGLAND, IRA GOULD Secty. Natl. Automatic Sprklr. Assn., 80 Maiden Lane, New York, N. Y.	Apr. 27, 1910
HOBBS, ROY A. Supt. Water Wks., Barnesville, Ohio.	Nov. 23, 1915
HOBBY, ARTHUR, S., C.E. Central Fé, Salamanca, Provincia de Santa Clara, Cuba.	June 8, 1909

HODGKINS, H. C., C.E. — Apr. 18, 1888
513 Dillaye Bldg., Syracuse, N. Y.

HODGMAN, BURT B., C.E. — July 18, 1907
50 Church St., New York, N. Y.

HODKINSON, THOMAS — June 24, 1913
Supt. Water Wks., 14 King St., London, Ontario, Can.

HOFFMASTER, GEORGE EDWARD — May 13, 1916
Amer. Water Wks., & Guar. Co., 50 Broad St., New York, N. Y.

HOLLEY, C. R. — Feb. 11, 1917
Supt. Water Wks., P. O. Box 608, Bessemer, Mich.

HOLLMAN, EDWARD E. — Apr. 14, 1915
San. Chem., 3900 Lexington Ave., St. Louis, Mo.

HOLMES, A. G. — July 10, 1906
P. O. Box 252, East Pittsburgh, Pa.

HOLMES, M. G. — Aug. 3, 1918
Supt. Water Works, Rochester, Minn.

HONE, FREDERIC DEP., C.E. — Dec. 18, 1913
13-21 Park Row, New York, N. Y.

HOOPER, THOMAS N. — Apr. 16, 1884
V.-Prest. Water Co., Davenport, Iowa.

HOOPES, EDGAR M., JR., C.E. — June 24, 1913
Ch. Engr., Water Dept., Wilmington, Del.

HOOVER, CHARLES P. — June 24, 1913
Chem. Filtration Plant, Columbus, Ohio.

HOPKINS, CHARLES COMSTOCK — June 10, 1911
Hyd. & San. Engr., 349 Cutler Bldg., Rochester, N. Y.

HOPKINS, NEWTON F., C.E., — July 18, 1907
801 Home Trust Bldg., Pittsburgh, Pa.

HOPPER, WALTER C. — June 10, 1911
Supt. Aquackanonk Water Co., 145 Prospect St., Passaic, N. J.

HORNER, CHARLES M. — June 24, 1903
Supt. Water Works Co., 1705 State St., East St. Louis, Ill.

HORNER, HARRY H. — May 19, 1916
Supt. Water Wks., 2114 First Ave., Birmingham, Ala.

HORNUNG, GEORGE — July 14, 1887
Cons. C. & Mech. Engr., Woolsack Building, Newport, Ky.

HORTON, ROBERT E., H.E. June 10, 1911
57 North Pine Ave., Albany, N. Y.

HORTON, THEODORE July 18, 1907
Ch. Eng., N. Y. State Dept. of Health, 206 Lancaster St., Albany, N. Y.

HOSTETLER, WILLIAM A. May 8. 1915
Supt. Iowa City Water Wks., 227 N. Capitol St., Iowa City, Ia.

HOUSE, G. O. Apr. 27, 1910
Mgr. St. P. Div., No. States Power Co., 76 West 3rd St., St. Paul, Minn.

HOWARD, FRANK E. Mch. 25, 1918
Prest. Bd. Water Comrs., 438 Asylum St., Hartford, Conn.

HOWELL, DAVID J., C.E. Oct. 23, 1914
Union Trust Bldg., Washington, D. C.

HOWSON, LOUIS R. May 3, 1916
Asst. Engr. for Alvord & Burdick, 617 E. 50th Place, Chicago, Ill.

HUBBELL, CLARENCE W. June 24, 1903
Cons. Eng., 2348 Penobscot Bldg., Detroit, Mich.

HUDSON, LEO June 24, 1913
Cons. Engr. 3265 Piedmont Ave., Pittsburgh, Pa.

HUGGANS, D. E. May 27, 1896
Mgr., Water Wks., Streator, Ill.

HUGGANS, R. D. Apr. 19, 1915
Ch. Engr., Streator Aqueduct Co., Streator, Ill.

HULETT, MASON Jan. 20, 1916
c/o R. U. V. Co., 50 Broad St., New York, N. Y.

HUMPHREY, E. W. June 24, 1913
Genl. Supt., 1117 Myrtle St., Erie, Pa.

HUNTER, HENRY G. June 10, 1911
N. Y. Cont. Jewell Filtn. Co., 619 New Birks Bldg., Montreal, Can.

HUNTER, T. B. July 10, 1906
Cons. Engr., 703 Rialto Bldg., San Francisco, Cal.

HUSTON, R. C. June 8, 1909
Civ. & Cons. Engr., P. O. Box 326, Maryville, Tenn.

HUY, HARRY F. May 30, 1916
Genl. Mgr. Western N. Y. Water Co., 704 Elect. Bldg. Buffalo, N. Y.

HYDE, CHARLES GILMAN July 18, 1907
Capt. San. Corps, N. A., Co. 28, Bat. 7, Camp Greenleaf, Ga.

HYMAN, H. H. Mgr. Miami Water Co., Miami, Fla.	Apr. 14, 1916
HYMMEN, H. Supt. Water Wks., Kitchener, Ontario.	June 8. 1909
INMAN, A. W. Supt. Massillon Water Supply Co., Massillon, Ohio.	Nov. 23, 1915
INOUE, S. 290 Harajiku, Tokyo, Japan.	July 18, 1907
IRWIN, RALPH EDWARD Capt. San. Corps, N. A., Edgewood Arsenal, Edgewood, Md.	June 8, 1904
IRWIN, THOMAS E. Huntington, N. Y.	June 10, 1911
ISAAC, F. N. Secty. & Genl. Mgr. The Hanford Water Co., Hanford, Cal.	May 12, 1908
JACKSON, DANIEL D. San. Expert, Engrg. Bldg., Columbia Univ., New York, N. Y.	Apr. 27, 1910
JACKSON, ROBERT A. Supt. Ins. & Water Co., Norristown, Pa.	June 24, 1893
JACOBSON, ANDREW Chem. Met. Water Dist. of Omaha, Florence, Neb.	Mch. 28, 1914
JAMES, CLAUDE L. City Engr. Supt. Water Wks., City Bldg., Mattoon, Ill.	Mch. 4, 1915
JARVIS, ALEXANDER CHARLES Capt. Royal Engrs., War Office, London.	Jan. 5, 1914
JENKS, HARRY NEVILLE San. Engr., Burma Mines, Ltd. Namtu, Northern Shan States, Burma, India.	Feb. 11, 1917
JENNINGS, CHARLES A. Rm. 466, Peoples Gas Bldg., Chicago, Ill.	May 12, 1908
JENSON, J. ARTHUR Supr. Water Wks. Dept. Minneapolis, Minn.	June 10, 1911
JENSON, MARION A. 4324 Parker St. Omaha, Neb.	Feb. 22, 1918
JENSON, J. CHRIS. Municipal Water Wks., Council Bluffs, Iowa.	June 4, 1912
JOHNSON, EDGAR W. Asst. Engr. Water Dept, 2632 14th Ave., S. Minneapolis, Minn.	July 20, 1917

JOHNSON, GEORGE A. — July 18, 1907
Major Q. M. C., N. A., Cons. Div., M. & R. Bch., Building C, 7th & B Sts. Washington, D. C.

JOHNSON, H. B. — June 24, 1913
Genl. Mgr. Sheffield Co., Sheffield, Ala.

JOHNSON, H. E. — Dec. 22, 1915
Supt. Elect. Lt. & Water Plant, Senatobia, Miss.

JOHNSON, PETER — May 30, 1916
Supervising Engr., Dept. W. S. G. & E. of New York, Bellmore, L. I., N. Y.

JOHNSTON, WILLIAM J. — April 3, 1917
Supt. Water Wks., Marquette, Mich.

JONES, A. J. — April 16, 1884
P. O. Box 273, New Brunswick, N. J.

JONES, BURKE — June 24, 1913
Supt. Water Wks., Hattiesburg, Miss.

JONES, GRANDVILLE R. — May 12, 1908
Assoc. Prof. of C. Engrg., Johns Hopkins Univ., Baltimore, Md.

JONES, HIRAM F. — July 18, 1907
Supt. Water Wks., 823 Walnut St., Elmira, N. Y.

JONES, J. M. — May 13, 1916
Bristol & Warren Water Works, Bristol, R. I.

JONES, J. W. — April 27, 1916
Mgr. Water Wks., Selma, Ala.

JONES, WILLIAM CLAYTON — May 12, 1914
426 Market St., Camden, N. J.

JONES, WILLIAM NELSON, C.E. — Aug. 19, 1914
City Engr's Office, City Hall, Minneapolis, Minn.

JORDAN, EDWIN O. — Oct. 26, 1914
Prof. of Bact., Univ. of Chicago, Chicago, Ill.

JORDAN, FRANK C. — June 10, 1911
Secty. Water Co., 113 Monument Pl., Indianapolis, Ind.

JUDD, W. A. — May 8, 1915
Supt. Water Wks., 20 Sixth St., N. E., Mason City, Ia.

KABLE, EDGAR P. — Nov. 19, 1917
Asst. Secty. York Water Co., 42 East Market St., York, Pa.

KAHN, LEON I. — May 30, 1916
Comnr. of Pub. Util., Shreveport, La.

KAPOUSTINE, THEODORE N. San. Engr., 819 Flatiron Building, New York, N. Y.	Aug. 28, 1917
KASTBERG, KARL C. City Engr., Des Moines, Ia.	June 7, 1904
KEBLER, H. E. 633, The Rookery, Chicago, Ill.	July 14, 1887
KEEN, HAROLD PEROT 306 Otis Bldg., 112 S. 16th St., Philadelphia, Pa.	Nov. 23, 1915
KELIHER, TIMOTHY Supt. Williamsport Water Co., Williamsport, Pa.	Feb. 24, 1917
KEILS, ANTHONY Supt. Bd. of Pub. Wks., 38 Moross Ave., Mt. Clemens, Mich.	June 8, 1909
KELLER, OSCAR E. Prest. Bd. Water Comnrs., 25 E. 5th St., St. Paul, Minn.	June 26, 1918
KELLY, EARL W. Water Lt. Dept., Duluth, Minn.	June 4, 1912
KEMBLE, F. T. Secty. New Rochelle Water Co., 238 Main St., New Rochelle, N. Y.	June 28, 1915
KERN, PETER Mgr. Water Dept., Fort Madison, Ia.	Oct. 24, 1917
KIENLE, JOHN A. San. Engr., 18 E. 41st Street, New York, N. Y.	June 8, 1909
KILLAM, SAMUEL E. Supt. Pipe Line & Reservoirs, 1 Ashburton Pl., Boston, Mass.	Nov. 24, 1914
KILPATRICK, JOHN D., C.E. Lieut.-Col. Q. M. C., N. G. U. S., Am. Exp. Forces.	June 4, 1912
KIMBALL, FRANK C. Asst. Treas. & Mgr., Commonwealth Water & Lt. Co., Summit, N. J.	June 11, 1902
KING, CHARLES PENROSE Engr. Bexhill Water & Gas Co., 5 Sedgwick Rd., Bexhill-on-Sea, England.	June 14, 1916
KINGMAN, HORACE Comnr. & Supt., City Hall, Brockton, Mass.	Mar. 17, 1916
KINNAIRD, ROBERT N. Supt. Des Moines Water Co., Des Moines, Ia.	June 4, 1912
KIRK, CLARENCE L. Prest. Indianapolis Water Co., 113 Monument Circle, Indianapolis, Ind.	June 8, 1907

KIRKPATRICK, EARL T. Lieut. U. S. R., Co. H, 42d Inf., Newport News, Va.	Feb. 11, 1917
KIRKPATRICK, WALTER G. Cons. Hyd. Engr., 704 Farley Bldg., Birmingham, Ala.	Apr. 27, 1910
KLARE, R. W. Mgr. Wabash Water & Lt. Co., Wabash, Ind.	June 28, 1915
KLAUS, FRED J. Asst. Engr. East Bay Water Co., 2414 Dana St., Berkeley, Cal.	Oct. 21, 1915
KLEIN, FEDERICO Cia Alumbrado Electrico, San Salvador, C. A.	Mch. 5, 1918
KLEIN, WILLIAM I. Roberts Filter Mfg. Co., Darby, Philadelphia, Pa.	June 24, 1913
KLINGBERG, W., C.E. 50 Church St., New York, N. Y.	July 10, 1906
KNEEN, A. H., C.E. 121 N. Broad St., Philadelphia, Pa.	June 10, 1911
KNICKERBACKER, JOHN, C.E. Prest. Eddy Valve Co. 86 1st St., Troy, N. Y.	June 24, 1913
KNISELY, J. HERMAN Ch., Bur. of Municipalities, Harrisburg, Pa.	Aug. 3, 1916
KNOWLES, CLARENCE R. Supt. Water Dept., I. C. R. R., 6504 Greenwood Ave., Chicago, Ill.	June 24, 1913
KNOWLES, MORRIS Cons. Engr., 1200 Jones Law Bldg., Pittsburgh, Pa.	July 18, 1907
KNOX, STUART K. Hill & Ferguson, 100 William St., New York, N. Y.	June 8, 1909
KOHN, C. L. Comnr., City Hall, Elgin, Ill.	June 24, 1913
KONTKOVSKI, EUGENE B. Cons. Engr., Nikolajevskaja, 17 log. 5, Petrograd, Russia.	Jan. 12, 1915
KRAUSE, MARK C., C.E. 335 Pine St., Williamsport, Pa.	May 30, 1916
KRIEGER, ALBERT A. Roberts Filter Co., Darby, Pa.	Apr. 22, 1916
KRIEGSHEIM, HEINRICH c/o Permutet Co., 440 4th Ave., New York, N. Y.	May 14, 1915
LABERGE, FRANÇOIS CHARLES Cons. Engr., 30 St. James St., Montreal, Can.	Mch. 10, 1916

LACOUNT, H. O. — May 12, 1908
Engr. & Asst. Secty. Insp. Dept. Factory Mutual Ins. Co., 124 College Ave., West Somerville, Mass.

LAFRENIERE, THEO. J. — June 24, 1916
San. Engr., Bd. of Health of P. Q., 9 St. James St., Montreal, Can.

LANCE, JOHN H. — May 10, 1917
Ch. Engr., The Spring Brook Water Supply Co., 30 N. Franklin St., Wilkes-Barre, Pa.

LANCE, OSCAR M. — July 18, 1907
Genl. Mgr. The Spring Brook Water Co., P. O. Box 124, Wilkes-Barre, Pa.

LANDMANN, L. B. — Sept. 19, 1914
Supt. Capital City Water Co., Jefferson City, Mo.

LANDRY, J. A. — Apr. 27, 1910
Prest. Ry. Lt. & Water Wks. Co., Lake Charles, La.

LARMON, FRANK P. — Apr. 22, 1914
Ch. Engr. Met. Water Dist., Omaha, Neb.

LASSO, ALFREDO F. — Oct. 24, 1917
Ing. Civ.. Obras Sanitarias de la Nacion, Buenos Aires. R. Argentina.

LATOURRETTE, FREDERICK, C.E. — Dec. 30, 1914
Engr. in Chge. J. C. Water Wks., 49 Highland Ave., Jersey City, N. J.

LAUTZ, W. E. — May 27, 1896
Secty. & Mgr. Pekin Water Wks., Pekin, Ill.

LAWLOR, FRANCIS D. H. — July 10, 1906
Supt. Citizens Water Co., Burlington, Ia.

LAWTON, RALPH W. — July 10, 1906
Mgr. Jewell Export Filter Co., 10 Clive St., Calcutta, India.

LAYNE, M. E. — June 4, 1912
Layne & Bowler Co., Randolph Bldg., Memphis, Tenn.

LEA, RICHARD S. — May 12, 1908
Cons. Engr., 809 New Birks Bldg., Montreal, Can.

LEACH, WILLIAM J. — Mar. 25, 1918
Supt. & Chf. Engr., 725 Mountain Ave., Fergus Falls, Minn.

LEAF, C. E. — Apr. 19, 1915
Ch. Chem. C. B. & Q. R. R. Laboratory, Aurora, Ill.

LECLERC, PIERRE — May 1, 1917
Supt. Eastern Div. Water Wks., 106 Clarke St., Montreal, Can.

LEDDEN, ERNEST M. June 4, 1912
404 Fourth Ave., New York, N. Y.

LEDOUX, J. W. July 18, 1907
Ch. Engr. Amer. Pipe & Constr. Co., 112 N. Broad St., Philadelphia, Pa.

LEE, CHARLES H. June 24, 1913
Lieut. U. S. R., 26th Engrs., Co. C. Water Sup. Sect., Am. Exp. Forces.

LEE, H. R. Feb. 24, 1917
City Chem., 440 W. Macon St., Decatur, Ill.

LEERSKOV, A. D. Apr. 20, 1918
Supt. Municipal Water Works, Lock Box 7, Brush, Col.

LEET, J. N. June 10, 1911
Supt. Water Dept., North East, Pa.

LEISEN, THEODORE A. June 7, 1904
Major Q. M. R. C. Constructing Q. M., Camp Custer, Mich.

LEOPOLD, F. B. May 12, 1914
Farmers Bk. Bldg., Pittsburgh, Pa.

LESAGE, ROYAL, C.E., B.S. Mch. 14, 1916
76 St. Gabriel St., Montreal, Can.

LESAGE, THOMAS WILLIAM April 4, 1916
Engr., Supt. Water Wks., City Hall, Montreal, Can.

LETTON, H. P. Jan. 12, 1915
Capt. Engrs. U. S. R. Water Sup. Service, Am. Exp. Forces.

LEVY, A. G. April 27, 1910
Asst. Dir. N. O. Purif. Plant, 8417 Panola St., New Orleans, La.

LEWIS, J. M. June 24, 1913
Supt. Parks & Pub. Prop., Sioux City, Ia.

LEWIS, R. E. May 12, 1908
Supt. Water Wks., Elizabeth City, N. C.

LIGHTFOOT, J. C., JR. June 23, 1914
N. J. Water Serv. Co., 1307 Real Est. Tr. Bldg., Philadelphia, Pa.

LILES, FLOYD L. June 26, 1918
Chrmn. Water Works, Spartanburg, S. C.

LITTLE, BEEKMAN C. June 24, 1903
Supt. Water Wks., 44 City Hall, Rochester, N. Y.

LIVEZEY, W. B. May 14, 1915
Prest. Newport News Lt. & Water Co., Newport News, Va.

LOBO, CARLOS — June 23, 1916
Actg. Dept. Ch. Engr., Dept. Water Sup., Gas & Electy., Municipal Bldg., New York, N. Y.

LOCHRIDGE, ELBERT E. — July 10, 1906
Engr. Water Dept., P. O. Box 1238, Springfield, Mass.

LOFTON, H. M. — June 4, 1912
Chattanooga, Tenn.

LONG, GEORGE J. — Apr. 23, 1915
Prest. Inter-State Water Co., Louisville, Ky.

LONG, JAMES H. — May 12, 1916
City Hall, Camden, N. J.

LONGLEY, FRANCIS F. — July 18, 1907
Lieut.-Col. 26th Engrs., Am. Exp. Forces.

LONGLEY, FREDERICK J. — Dec. 1, 1913
Lieut. Aviation Sec. S. C., Cmdg. Of., 271 Aero Squad. Ellington Field, Tex.

LOOMIS, E. L — July 10, 1906
Supt. Valparaiso Home Water Co., Valparaiso, Ind.

LORD, FRANKLIN B., JR. — June 10, 1911
Queens Co. Water Co., Cedarhurst, L. I., N. Y.

LORD, CHARLES H. — Aug. 10, 1918
Supt. Water Works, Ogdensburg, N. Y.

LOTT, ERSKINE H. — May 30, 1916
Supt. Flatbush Water Wks. Co., 785 Flatbush Ave., Brooklyn, N. Y.

LOUNSBURY, WILLIAM C. — May 12, 1908
Genl. Supt. Superior Water, Lt. & Power Co., Superior, Wis.

LOVEJOY, WILLIAM H. — June 4, 1912
Louisville Water Co., Louisville, Ky.

LUCAS, HUGH L. — Apr. 27, 1910
Supt. Water Pipe Exten., 404 City Hall, Chicago, Ill.

LUCE, FRANCIS H. — May 12, 1914
Supt. Woodhaven Water Supply Co., Woodhaven, N. Y.

LUDLOW, J. L. — June 7, 1904
Cons. Engr., Winston-Salem, N. C.

LUSCOMBE, WILLIAM — May 12, 1908
V.-Prest. Gary Heat, Lt. & Water Co., Gary, Ind.

LUTHER, J. N. — June 26, 1918
Supt. Water Works, South Bend, Ind.

LYONS, B. F. V.-Prest. & Genl. Mgr. Beloit Water, Gas & Elect. Co., Beloit, Wis.	May 12, 1908
MCALPINE, A. H. Genl. Western Agt. Hersey Mfg. Co., 211 Schultz Bldg., Columbus, Ohio.	April 27, 1889
MCCABE, H. DALLAS, C.E. 800 Donner Ave., Monessen, Pa.	May 12, 1908
MCCARTHY, DANIEL B. Treas. Waterford Water Wks. Co., 50 East 42d St., New York, N. Y.	June 27, 1905
MCCARTHY, WILLIAM Supt Water Wks., Bluefield, W. Va.	May 12, 1908
MCCLENAHAN, W. T. 64 W. Randolph St., Chicago, Ill.	May 12, 1914
MCCLINTOCK, JAMES R. 170 Broadway, New York, N. Y.	Jan. 27, 1914
MCCORMICK, ROBERT Co. D, 26th Engrs., Camp Dix, N. J.	Nov. 1, 1916
MCCRADY, MACHARVEY Chem. & Bact. Bd. of Hlth. of P. Q., 9 St. James St., Montreal, Can.	Apr. 14, 1916
MCDONALD, CHARLES E. Supt. Water Wks., Waterbury, Conn.	June 10, 1911
MCDONNELL, ROBERT E. 402 Interstate Bldg., Kansas City, Mo.	June 24, 1913
MCFARLAND, CHESTER R. Secty. & Genl. Mgr. Water Wks. Co., Tampa, Fla.	May 12, 1908
MCGIBONEY, J. H. Mgr. Water Wks., Middleborough, Ky.	May 14, 1915
MCGINTY J. H. Supt. Water Wks., Mansfield, Ohio.	May 10, 1917
MCGONIGALE, WILLIAM J. P.O. Box 2360, Louisville, Ky.	June 4, 1912
MCGRATH, F. R. Supt. Water Wks., City Hall, Chambersburg, Pa.	May 12, 1914
MCINNES, F. A. Div. Engr., Pub. Wks. Dept., 23 Salcombe St., Dorchester, Mass.	May 12, 1914
MCINTOSH, WILLIAM, JR. Castle Stuart Dalcross, Inverness-Shire, Scotland.	June 24, 1913

McKenzie, S. H. — Apr. 14, 1916
Engr., & Supt. Terryville and Southington Water Wks., Southington, Conn.

McKim, Robert Albert, C.E. — June 4, 1912
65 W. 88th St., New York, N. Y.

McLaughlin, George E., M.D. — June 24, 1913
Lieut. U. S. Navy, Asst. Surgeon, Naval Station, Hampton Roads, Va.

McMane, William I. — Mch. 1, 1916
Supt. Commonwealth Water Co., 18 Maple Ave., Summit, N. J.

McMillan, T. W. — Dec. 22, 1915
Supt. Water Wks., Mt. Pleasant, Ia.

McRae, H. C. — Apr. 27, 1910
1st Lieut. 318th Engineers, E. O. R. C., Vancouver Barracks, Washington

McRae, John B. — May 3, 1916
Cons. Eng., 310 Booth Bldg., Ottawa. Can.

McReynolds, B. B. — May 12, 1914
Supt. Water Wks., City Hall, Colorado Springs, Colo.

McWilliams, C. Q. — June 18, 1901
Prest. Roaring Crk. Water Co., P. O. Box 85, Shamokin, Pa.

MacDonald. Emmett — June 7, 1904
Mgr. Lincoln Water & Lt. Co., Lincoln, Ill.

MacDonald, W. E. — May 10, 1917
City Water Wks., Engr., 93 Powell Ave., Ottawa, Can.

Machen, Henry B. — May 12, 1908
Major O. R. C. Explosives Sect., Buffalo, N. Y.

Mackie, George D. — Feb. 11, 1917
City Comnr., Moose Jaw, Saskatchewan.

Maffitt, Dale L. — Apr. 20, 1918
Chem. & Bact., Des Moines Water Co., Des Moines, Ia.

Main, Geo. A. — Apr. 27, 1910
Supt. Water & Sew. Depts., Daytona, Fla.

Mallalieu, Willard C. — Dec. 30, 1914
Capt. S. C., N. A., 28 Co. Btln. 7, M. O. T. C., Camp Greenleaf, Ga.

Manahan, Elmer G., C.E. — June 8, 1909
Desgng. Engr., Bd. of Water Supply, Municipal Bldg., New York, N. Y.

MANGOLD, JOHN F., C.E. June 24, 1913
Rapid City, S. Dak.

MANVILLE, F. D. June 18, 1901
Local Mgr. Lt. & Water Co., Newport News, Va.

MANZ, LOUIS C., M.E. June 8, 1904
1500 W. Allegheny Ave., Philadelphia, Pa.

MARTIN, A. M. May 12, 1908
Waco, Texas.

MARTIN, J. C. May 14, 1915
Atty. for Ohio Water Wks. Assn., 8 E. Long St., Columbus, Ohio.

MASON, S. J. May 10, 1917
Engr. & Supt. Water Wks., Perth Amboy, N. J.

MASON, WILLIAM P., M.D. May 18, 1892
Prof. of Chem. Ren. Poly. Inst., Troy, N. Y.

MATTE, HUBERT P. T. June 4, 1912
Supt. Water Dept., Oak Park, Ill.

MAURICE, GEORGE HOLBROOKE, C.E. June 10, 1911
Eagle Springs, N. C.

MAURY, DABNEY H. Aug. 22, 1894
Lieut.-Col. Q. M. C., N. A., Adv. Engr. on Water Supply, Constr. Div., Washington, D. C.

MAVITY, J. W., C.E. May 14, 1915
806 N. Jefferson St., Wellington, Kans.

MAXWELL, DONALD H. Feb. 24, 1917
Asst. Engr. with Alvord & Burdick, 1417 Hartford Bldg., Chicago, Ill.

MAYO, WILLIAM B. June 4, 1912
c/o Ford Motor Co., Detroit, Mich.

MEAD, DANIEL W., C.E. Apr. 17, 1889
120 W. Gorham St., Madison, Wis.

MEARS, BRAINERD June 28, 1915
Prof. of Chem., Williams College, Williamstown, Mass.

MEEKER, GEORGE R. May 19, 1916
Supt. Water Wks., Geneseo, N. Y.

MELLEN, A. F. Apr. 23, 1915
City Chemist, Filt. Plant, Moline, Ill.

MELLON, T. A. June 24, 1903
Prest. Kensington Water Co., 514 Smithfield St., Pittsburgh, Pa.

MERCIER, PAUL-EMILE — Apr. 18, 1916
Ch. Engr. & City Svyr., City Hall, Montreal, Can.

MERCK, WILLIAM E. — June 18, 1916
Supt. Water & Lt. Dept., Jackson, Ga.

MESSER, RICHARD — June 10, 1911
Major Q. M. C., N. A., Cons. Div. M. & R. Bch., Washington, D. C.

MESSER, SAMUEL F. — Nov. 23, 1915
Supt. Kent Water & Lt. Co., Kent, Ohio.

METCALF, JOHN T. — June 28, 1916
Asst. Engr., in Chge. L. I. Watershed, 625 West St., Brooklyn, N. Y.

METCALF, LEONARD — June 24, 1903
Cons. Civil Engr., 14 Beacon St., Boston, Mass.

MEYERS, A. H. — June 24, 1903
Supt. Water Co., Columbia, Pa.

MICHEL, B. G. — June 8, 1916
City Engr., Kitchener, Ontario. Can.

MICHIE, JOHN C., C.E. — June 24, 1903
Supt. Water Co., Durham, N. C.

MICKLE, F. LEE — Feb. 11, 1917
State Dept. of Hlth., 135 Huntington St., New Haven, Conn.

MIDDLEMISS, GEORGE A., C.E. — Apr. 27, 1910
Supr. of Plmbg., 602 Carondelet St., New Orleans, La.

MILLER, CARROLL — June 23, 1916
Genl. Mgr. Murphysboro Water Wks. & Elect. & Gas Lt. Co., Aurora, Ill.

MILLER, CLARENCE F., M.E. — Apr. 4, 1916
941 E. Ontario St., Philadelphia, Pa.

MILLER, CLIFFORD N., H.E. — May 14, 1915
2807 Union Central Bldg., Cincinnati, Ohio.

MILLER, EDWIN E. — Mch. 28, 1914
Asst. Supt. Power Plants, Hackensack Water Co., Weehawken, N. J.

MILLER, HIRAM ALLEN — June 10, 1911
Cons. Engr., 8 Beacon St., Boston, Mass.

MILLER, J. A. — June 8, 1909
Supt. Water Wks., 10 W. Third St., Alton, Ill.

MILLER, MELVILLE W. — May 14, 1915
Supt. Lafayette Water Wks., Lafayette, Ind.

MILLER, WALTER EDWARD — June 4, 1912
1719 Madison St., Madison, Wis.

MILLIGAN, R. E. Chem., P. O. Box A, Nutley, N. J.	June 11, 1902
MILNE, ALEXANDER Supt. Water Wks., St. Catharines, Ontario, Can.	June 24, 1903
MINOR, EDWARD EASTMAN Supt. New Haven Water Co., 91 Temple St., New Haven, Conn.	June 4, 1912
MITCHELL, CHARLES HAMILTON, C.E. Lieut.-Col. Chf. of Inteligence, 2d British Army, British Exp. Forces.	June 10, 1911
MITCHELL, GEORGE Lt. R. M. Engrs. H. M. S. *Impérieuse*, London, Eng.	June 24, 1913
MOAT, CHARLES P. Chem. State Bd. of Health, 184 Church St., Burlington, Vt.	Apr. 9, 1915
MOHLER, B. M. 1st Lieut. San. Corps, N. A., Am. Exp. Forces.	Feb. 24, 1917
MOHRHARDT, E. F. Secty. Bd. Fire Undwtrs. of the Pacific, 914 Merchants Exchange Bldg., San Francisco, Cal.	Oct. 10, 1917
MOLIS, WILLIAM Supt. Water Wks., Muscatine, Ia.	Mch. 15, 1882
MONFORT, WILSON F. Cons. Chem., 506 N. Vandeventer Ave., St. Louis, Mo.	July 10, 1906
MONTOULIEU, HENRY J., C.E. No. 10 Calle F, Vedado, Havana, Cuba.	June 4, 1912
MOORE, GEORGE H. Supt. Suburban Water Co., Verona, Pa.	May 12, 1908
MOORE, JOHN M. Cons. Engr., Palmer Block, London, Ontario.	July 10, 1906
MORGAN, HENRY B. Mgr. Peoria Water Wks. Co., 143 N. Jefferson Ave. Peoria, Ill.	Oct. 16, 1914
MORRIS, CHARLES H. Supr. of Water Wks., New Brunswick, N. J.	June 8, 1916
MORSE, ROBERT B. Ch. Engr. State Bd. of Health, 16 W. Saratoga St, Baltimore, Md.	May 8, 1915
MORY, A. V. H. Chem. Dir., Dept. 217, Sears, Roebuck & Co., Chicago, Ill.	Nov. 1, 1914

MUNDY, AMBROSE — Mch. 23, 1914
Supt. Middlesex Water Co., Woodbridge, N. J.

MURPHY, A. R., C.E. — June 10, 1911
Capt. E. R. C., Am. Exp. Forces.

MURPHY, FRANK J. — June 11, 1916
Supt. Div. of Meters, City Hall, Milwaukee, Wis.

MURPHY, L. E. — May 12, 1914
Supt. Water Dept., Jacksonville, Fla.

MURRAY, H. E. — May 8, 1915
Capt. Q. M. R. C., Scofield Barracks.

MURRIN, JOHN A. — June 28, 1916
Comnr. Pub. Prop., City Hall, Rock Island, Ill.

NEARY, JOHN H. — June 28, 1916
Supt. Wtr. Wks, 816 N. Chicago Ave., So. Milwaukee, Wis.

NEAVE, J. W. — May 10, 1917
Supt. Water Wks., Salisbury, N. C.

NELSON, FRED B., C.E. — July 18, 1907
966 Anderson Ave., Highbridge, New York, N. Y.

NEUT, GEORGE — June 10, 1911
Ch. Engr. Water Wks., Santiago, Chile, S. A.

NEVLING, J. B. — Oct. 16, 1914
Secty.-Treas. Clearfield Water Co., Clearfield, Pa.

NEWELL, C. W. — Apr. 11, 1917
Serv. Foreman of Maintenance, 2218 Elliott Ave., Minneapolis, Minn.

NEWELL, F. H. — Feb. 24, 1917
Cons. Engr., Prof. of C. Engrg., 201 Engrg. Hall, Urbana, Ill.

NEWHALL, WILLIAM G. — Feb. 24, 1917
Asst. Supt. Portland Water Dist., 42 Brentwood St., Portland, Me.

NEWLANDS, JAMES A. — Oct. 16, 1914
San. Engr., 11 Laurel St., Hartford, Conn.

NEYLON, C. M. B. LEIGH, C. & H.E. — May 8, 1915
State River & Water Supply Comn., Engrs. Branch, Treasury Gardens, Melbourne, Australia.

NICHOL, E. M., C.E. — June 13, 1916
212 S. 7th St., Philadelphia, Pa.

NICHOLS, A. E., C.E. — June 8, 1916
5331 Woodlawn Ave., Chicago, Ill.

NICHOLS, CHARLES SABIN — June 26, 1918
Assoc. Prof. in chg. of San. Eng., Iowa State College, Ames, Ia.

NISHIOEDA, SATORU Municipal Water Wks., Tokyo, Japan.	Oct. 16, 1914
NISSLY, E. L. Prest. Florin Water Co., Florin, Pa.	May 14, 1915
NOLTE, AUGUST G. Supt. Filter Plant, 4212 Red Bud Ave., St. Louis, Mo.	Dec. 20, 1916
NUEBLING, EMIL L. Ch. Engr., Bur. of Water, Reading, Pa.	May 29, 1895
NUTT, J. A. Supt. Water Wks., Monongahela, Pa.	Mch. 17, 1916
NYE, WILLIAM W., Trustee Kennebec Water Dist., Fairfield, Me.	May 12, 1908
O'CALLAHAN, C. D. City Engr., City Hall, Joliet, Ill.	June 13, 1916
O'MEARA, ROBERT J. Asst. Engr., Dept. of Water Supply, 311 E. 124th St., New York, N. Y.	Feb. 24, 1917
O'ROURKE, JAMES Supt. of Water Wks., Fulton, Ill.	Nov. 24, 1914
O'SHAUGHNESSY, JERRY Supt. Dept. of Water, Columbus, Ohio.	Apr. 27, 1910
O'SHAUGHNESSY, M. M. City Engr., 2732 Vallejo St., San Francisco, Cal.	July 18, 1907
OLMSTED, CHARLES S. Supt. Monterey Co. Water Wks., Pacific Grove, Cal.	May 3, 1916
ORCHARD, WILLIAM J. San. Engr., 137 Centre St., New York, N. Y.	Aug. 1, 1917
ORR, ALEXANDER, C.E. Ch. Engr. Water Wks., Gloversville, N. Y.	July 18, 1907
OTT, E. W. Supt., 23 Court St., Cortland, N. Y.	June 13, 1916
OWENS, ROBERT B., B.A., B.E. Govt. Bldgs., Edmonton, Alberta, Can.	Apr. 22, 1914
PARKER, C. B. Asst. Supt. Pipe System, Hackensack Water Co., Weehawken, N. J.	Dec. 30, 1914
PARKER, CHARLES T. Ch. Engr. Alton Water Co., 346 Jefferson St., Alton, Ill.	Apr. 21, 1915
PARR, S. W. Prof. App. Chemistry, Univ. of Ill., Urbana, Ill.	Apr. 21, 1915

Pate, R. L. Mgr. City Water Co., Springfield, Mo.	June 10, 1911
Patrick, Charles G. Genl. Mgr., Goldfield Water Co., P. O. Box 829, Goldfield, Nev.	May 3, 1916
Patterson, Wm. G. Supt., 20 Gerald Ave., Highland Park, Mich.	May 14, 1915
Patton, W. A. Prest. & Mgr. Water Co., Catlettsburg, Ky.	June 7, 1904
Patton, W. S. Secty. Ashland Water Wks. Co., Ashland, Ky.	May 10, 1917
Payson, Edgar R. Mgr. Water Wks., 93 Exchange St., Portland, Me.	June 27, 1905
Pearse, Langdon The San. Dist. of Chicago, Karpen Bldg., 900 S. Michigan Ave., Chicago., Ill.	June 24, 1913
Peart, John Water Supply Engr., Met. W. S. & S. Bd. Brisbane, Queensland.	Oct. 9, 1916
Peck, Ermon M. Cons. Engr., Rm. 33, 26 State St., Hartford, Conn.	July 18, 1907
Pedroso, Alex. M., M.D. 40 José Bonifacio, San Paulo, Brazil.	May 1, 1917
Perrow, Mosby Garland Health Officer, Lynchburg, Va.	May 1, 1917
Perry, William Hyd. Engr., Maplewood Ave., Cote des Neiges, Montreal, Quebec.	June 26, 1886
Peter, W. F. Supt. Seymour Water Co., Seymour, Ind.	May 3, 1916
Peterson, Edward Mgr. Water Wks. & Lt. Plant, Crookston, Minn.	June 10, 1911
Phelps, Earle B. Chem. Hyg. Lab., 25th & E Sts., Washington, D. C.	Oct. 23, 1914
Phillips, Clifford French Cons. Engr., 801 Internat. Life Bldg., St. Louis, Mo.	Apr. 9, 1915
Phillips, Hiram Cons. Engr., 715 Internat. Life Bldg., St. Louis, Mo.	June 4, 1912
Phillips, T. C. Water Wks. Engr., 1003 City Hall, Chicago, Ill.	June 27, 1905

PIRNIE, MALCOLM — May 10, 1917
1st Lieut. R. T. C., N. A., Am. Exp. Forces.

PITCHER, F. H. — June 27, 1905
Gen. Mgr. & Ch. Engr., Montreal Water & Power Co., Place D'Armes Square, Montreal, Can.

PITNEY, FREDERIC V., C.E. — Nov. 19, 1914
21 South St., Morristown, N. J.

PLAMONDON, ADRIEN, C.E. — Mch. 27, 1916
Engr. and Contr., 70 St. James St., Montreal, Can.

PLATTNER, WILLIAM — Apr. 27, 1910
Cons. Engr., North Attleboro, Mass.

POLAND, JOHN A. — Oct. 23, 1917
Secty. & Atty., Gas. Lt. & Wtr. Co., Chillicothe, O.

POLLARD, SEABURY G. — June 4, 1912
Cons. Engr., 3422 Burch Ave., Cincinnati, O.

POLLARD, W. D. — May 18, 1892
Genl. Mgr. Pottsville Water Co., Pottsville, Pa.

PORTER, D. P. — Oct. 9, 1916
Supt. Water Wks., 1502 E. 8th St., Pueblo, Col.

POTTER, ALEXANDER — July 18, 1907
Cons. Engr., 50 Church St., New York, N. Y.

POTTER, CHARLES S. — Apr. 27, 1910
Purch. Agt. Water Co., Louisville, Ky.

POTTS, CLYDE — July 10, 1906
C. & San. Engr., 30 Church St., New York, N. Y.

POWELL, ALEXANDER C. — Apr. 27, 1910
Chem. Bangor Filter Plant, Bangor, Me.

POWELL, SHEPPARD T. — July 10, 1906
Chem. Baltimore Co. Water & Electric Co., 100 W. Fayette St., Baltimore, Md.

POWERS, JEROME, C. E. — Mch. 11, 1917
1st Lieut. 24th Engrs., U. S. R., Am. Exp. Forces.

POWNALL, WILLIAM A. — May 5, 1915
Water Engr. Wabash R. R., Decatur, Ill.

PRACY, GEO. WESLEY — May 14, 1915
Asst. Supt. Dept. Operation and Maintenance, 2477 21st Ave., San Francisco, Cal.

PRATT, CHARLES — May 14, 191
City Engr. & Supt. Water Wks., 1315 S. Santa Fé Ave., Chanute, Kans.

PRATT, GILBERT H. — June 8, 1916
Chem. and San. Engr., Box A, Nutley, N. J.

PRAY, JOHN W. Supt. Water Wks., Ft. Dodge, Ia.	June 24, 1913
PRICE, W. H. Genl. Mgr., Etowah Water & Lt. Co., Box 628, Etowah, Tenn.	May 23, 1916
PRINCE, GEORGE T., C.E. Omaha Water Bd., Omaha, Neb.	July 10, 1916
PROBASCO, SELDEN R., C.E. Burlington, N. J.	Apr. 14, 1916
PROVOST, ANDREW J., JR. San. Expert & Hyd. Engr., 39–41 W. 38th St., New York, N. Y.	May 12, 1908
PRUETT, G. C., C.E. City Engr. & Supt. Water Wks., Box 673, Miles City, Mont.	Feb. 25, 1914
PUGH, MARSHALL R., C.E. Major 21st Engrs., Am. Exp. Forces.	Apr. 27, 1910
PURDY, J. H. c/o Amer. Water Wks. & Elect. Co., 50 Broad St., New York, N. Y.	May 27, 1896
QUAYLE, LEROY A. Mech. Engr., Water Dept., 1455 W. 98th St., Cleveland, Ohio.	June 28, 1915
QUICK, ALFRED MERRITT, C.E. 725 Munsey Bldg., Baltimore, Md.	June 18, 1901
QUINN, M. P. Fidelity Bldg., Philadelphia, Pa.	May 12, 1914
RACE, JOSEPH City Bact. & Chem., Ottawa, Can.	May 12, 1914
RADER, R. P. Supt. Lehigh Water Co., Easton, Pa.	May 12, 1908
RAFFO, BARTOLOME M. Ing. de las Obras Sanitarias de la Nacion, Calle Moreno 2602, Buenos Aires, R. Argentina	Oct. 25, 1917
RAINS, J. M. Supt. Water Wks., Lebanon, Ky.	May 12, 1908
RAMSEY, WILLIAM H. C. Upland & Oakland Terrace, Bala, Pa.	May 6, 1916
RAPP, W. M. Supt. Constr. Water Dept., Atlanta, Ga.	May 17, 1899
RANDALL, W. H. Supt. Maintc., Wtr. Wks Dept., 188 Albany Ave., Toronto, Ont.	June 8, 1909

REAGAN, JOHN F., JR. — July 10, 1906
1137 Park Ave., Utica, N. Y.

RECTOR, FRANK LESLIE, M.D. — Apr. 16, 1914
Bacteriologist, 227 Fulton St., New York, N. Y.

REED, D. A. — June 24, 1913
Mgr. Water & Light Dept., Duluth, Minn.

REES, S. P., C. E. — May 9, 1917
170 Sprague Ave., Pittsburgh, Pa.

REID, WALTER — Apr. 19, 1915
Supt. Water Wks., Springfield, Ill.

REIMER, ARTHUR A. — May 12, 1908
45 So. Maple Ave., East Orange, N. J.

RELPH, O. S. — May 14, 1915
Supt. San. José Water Co., San José, Cal.

REYER, GEORGE — Apr. 16, 1884
Supt. Water Wks., Nashville, Tenn.

RHYNUS, CLARENCE PAULDING — June 4, 1912
Asst. San. Engr., U. S. Hyg. Lab., Washington, D. C.

RICE, P. D. — May 14, 1915
Engr. Redwood Mfrs. Co. 1600 Hobart Bldg., San Francisco, Cal.

RICHARDS, ARTHUR — Nov. 23, 1915
Cons. Engr. Richards Engrg. Co., 37½ E. Long St., Columbus, Ohio.

RIDER, JOSEPH B. — May 12, 1914
Cons. Engr., 29 Broadway, New York, N. Y.

RINGNESS, HENRY — Apr. 23, 1915
Asst. to Mgr. Peoria Water Wks. Co., 143–5 N. Jefferson St., Peoria, Ill.

RITCHIE, EDGAR GOWAR — June 24, 1915
Engr. of Water Supply, Met. Bd. of Wks., Melbourne, Australia.

ROBERTS, EARL I. — Jan. 7, 1918
Asst. Engr. State Dept. of Hlth., Columbus, Ohio.

ROBERTS, WILLIAM J. — Oct. 23, 1914
Ch. Engr. Inter-County River Improvement, 401 Court House, Tacoma, Wash.

ROBINSON, LEONARD C. — July 18, 1907
Supt. Water & Sewer Dept., Concord, Mass.

ROBINSON, WILLIAM P. — June 8, 1897
Chrmn. Bd. of Dir., The Denver Union Water Co., Denver, Colo.

Rodman, George Edward Asst. Engr. Dept., W. S. G. & E., 317 W. 99th St., New York, N. Y.	Feb. 10, 1917
Rohrbach, William R. Mgr. Sunbury Water Co., Sunbury, Pa.	July 10, 1906
Romig, C. O. Secty. & Supt. Wtr. Sup. Co., Dennison, O.	Oct. 23, 1917
Roos, Charles M. Supt. Cairo Water Co., Cairo, Ill.	June 24, 1913
Rosenthal, Helman Supt. & Chf. Chmst., Wtr. Purif. Plant, Dallas, Tex.	June 26, 1918
Rosentreter, Herman Prin. Asst. Engr. of Wks., Water Dept., City Hall, Newark, N. J.	Mch. 12, 1906
Ross, Charles H. Supt. Water Dept., Brockport, N. Y.	July 10, 1906
Ross, R. A. Cons. Engr., 80 St. Francis Xavier St., Montreal, Can.	June 15, 1914
Rudderow, Maurice B. Mgr. Merchantville Water Co., Merchantville, N. J.	June 25, 1914
Rue, J. A. Supt. Mattoon Clear Water Co., 1217 Marshall Ave., Mattoon, Ill.	Apr. 14, 1916
Ruge, Bernard A. Secty.-Treas. Ward Carpenter & Co., Cvil. & Constg. Engrs., Tarrytown, N. Y.	June 15, 1917
Russell, Norman F. S. 1421 Chestnut St., Philadelphia, Pa.	Dec. 22, 1915
Rust, C. H. National Club, Bay St., Toronto, Ont.	June 24, 1903
Ruttan, H. N. Brig. Genl. Cmndg. M. D., No. 10, Winnipeg, Manitoba	May 12, 1918
Ryan, William G. San. Engr., 34 West St., Florence, Mass.	Apr. 27, 1910
Sackett, Robert L. Dean, School of Engrg., Pa. State College, State College, Pa.	June 24, 1913
Salmon, C. B. Pub. Util. Broker, Beloit, Wis.	June 11, 1902
Salmond, James J. Mgr. *Canadian Engineer*, 62 Church St., Toronto, Ont.	July 18, 1907

SANDO, WILL J. Cons. Engr., 1338–39 Wells Bldg., Milwaukee, Wis.	June 27, 1905
SANDS, CHARLES G. Supt. Gt. South Bay Water Co., Bay Shore, N. Y.	May 13, 1916
SANZENBACHER, GEORGE Engr. & Supt. Dept. of Water, Newark, N. J.	June 27, 1905
SARGENT, GEORGE H. Supt. Water Wks. & City Engr., La Grange, Ga.	Apr. 12, 1916
SAUNDERS, FREDERICK WALTER THEODORE Port Augusta, South Australia.	May 12, 1908
SAVILLE, CALEB MILLS Mgr. & Chf. Engr. Wtr. Wks., Pilgara Building, Hartford, Conn.	Mch. 26, 1918
SAWIN, LUTHER R. Bact. in Chge. of Mt. Kisco Lab., Mt. Kisco, N. Y.	Aug. 3, 1916
SAYER, FRED D. Borough Engr. & Supt. of Water, Brookville, Jefferson Co., Pa.	Apr. 22, 1914
SCARTH, STANILAND Supt. Water, Sewer & Lt., Newark, N. Y.	Aug. 18, 1916
SCHARFF, MAURICE R. 1st Lieut. E. O. R. C., Am. Exp. Forces.	May 12, 1914
SCHAUP, CHARLES E. Cons. Engr., 36 S. 17th St., Harrisburg, Pa.	May 12, 1914
SCHNELLBACH, J. F. Asst. Engr. Ill. State Water Survey, Rm. 57, Chemistry Bldg., Urbana, Ill.	Feb. 14, 1917
SCHOLZ, ROBERT O. Asst. Engr. Dept. of Water, 45 Seymour Ave., Newark, N. J.	Mch. 1, 1916
SCHULZ, C. F. Cons. Engr., 1906 E. 105th St., Cleveland, Ohio.	July 10, 1906
SCHWABE, WALTER P. Prest. & Mgr. The Thompsonville Water Co., 15 Central St., Thompsonville, Conn.	Nov. 1, 1914
SCHWARTZ, FREDERICK W. 439 Hamilton St., Albany, N. Y.	July 18, 1907
SCHWINN, PHIL Genl. Mgr. City Wtr. Wks., Dubuque, Ia.	May 1, 1918
SCOTT, WALTER M. Cons. Engr., 188 Montrose St., River Heights, Winnipeg, Manitoba.	Mch. 28, 1914
SEIBERT, JOSEPH Supt. Water Wks., St. Cloud, Minn.	June 4, 1912

Semans, Carl R — June 8, 1904
Mgr. Water, Lt. & Power Co., Washington, Ind.

Senior, Samuel Palmer — July 10, 1906
V.-Prest. & Engr. Bridgeport Hydraulic Co., Bridgeport, Conn.

Sharp, John T., Jr. — Apr. 27, 1910
Supt. Elect. Lt. & Water Co., Canton, Miss.

Shaw, A. W. — June 10, 1911
Supt. Water Wks., Brandon, Manitoba, Can.

Shaw, F. H. — May 12, 1908
Civil, Hyd. & San. Engr., 310 Breneman Bldg., Lancaster, Pa.

Shaw, Jesse — June 8, 1916
Supt. City Water Wks., Topeka, Kan.

Shaw, Walter A. — July 10, 1916
State Pub. Util., 1509 Farwell Ave., Chicago, Ill.

Shepard, James A. — Apr. 20, 1918
Supt. Bisbee-Naco Water Co., Bisbee, Ariz.

Shepherd, A. B. — May 27, 1896
2d V.-Prest. Woodlawn Water Co., Pittsburgh, Pa.

Shepperd, F. W. — Apr. 18, 1888
Fire and Water Engineering, 154 Nassau St., New York, N. Y.

Sherman, Charles W. — May 12, 1914
Cons. Engr., 14 Beacon St., Boston, Mass.

Sherman, Richard U. — Apr. 27, 1910
87 Utica City Natl. Bk. Bldg., Utica, N. Y.

Sherman, Richard W. — Apr. 20, 1918
Cons. Engr., 104 S. Lake Ave., Albany, N. Y.

Sherman, Walter J., C.E. — May 12, 1908
The W. J. Sherman Co., Toledo, Ohio.

Sherrerd, Morris R. — June 7, 1897
Ch. Engr. St. & Water Comn., City Hall, Newark, N. J.

Shibley, Kenneth — Sept. 27, 1915
C. & Hyd. Engr., 1218 Merchants Exch., San Francisco, Cal.

Shields, W. S. — May 17, 1899
1201 Hartford Bldg., Chicago, Ill.

Shoemaker, G. E. — June 10, 1911
Secty. Water Wks., Waterloo, Ia.

Showell, Edward B., Jr. — June 24, 1913
du Pont Powder Co., City Point, Va.

Siddons, Joseph S. V.
Supt. Torresdale Filters, 1648 Dyre St., Phila phia, Pa.

Sieber, William
Supt. Water Wks., Henderson, Ky.

Siems, V. Bernard
Res. & Actg. Pitometer Engr., Water Dept., 1408 Chase St., Baltimore, Md.

Simonds, Fred W.
City Engr. & Supt. Water Works, Rahway, N. J.

Sjoblom, M. C.
Asst. Engr. State Bd. of Health, State Capi Springfield, Ill.

Sluyter, E. W.
Supt. Water Wks., Herkimer, N. Y.

Smith, Alva J.
City Engr. & Supt. of Water, Emporia, Kans.

Smith, Arthur H.
Engr., The Calco Chemical Co., Bound Brook, N

Smith, Charles H., M.E.
802 Grosvenor Bldg., Providence, R. I.

Smith, Charles Walter
336 Miller St., North Sydney, N. S. W., Australi

Smith, E. H.
Mgr. N. J. Water Serv. Co., 3 Ellis St., Haddonfi N. J.

Smith, Gordon Z.
c/o Bridgeport Hydraulic Co., Bridgeport, Con

Smith, J. J.
City Engr., 433 Maple Ave., Grand Forks, N. D.

Smith, J. Waldo
Ch. Engr. Bd. of Water Supply, Municipal Bl New York, N. Y.

Smith, Karl H.
Supt. Elect. Lt. & Water Wks., Grafton, N. D.

Smith, L. B.
Mgr. Westmoreland Water Co., Greensburg, Pa.

Smith, Leon A.
Supt. Water Wks., City Hall, Madison, Wis.

Smith, Merrett Haviland
Col. 104th F. A., Am. Exp. Forces.

Smith, Owen T.
Supt. Water Wks., Freeport, Ill.

SMITH, R. J. — June 10, 1911
Supt. Canadian Elect. Water Power Co., Ltd., Perth, Ontario.

SMITH, W. Z. — Apr. 27, 1910
Genl. Mgr. Water Wks., 442 Luckie St., Atlanta, Ga.

SMOOT, L. D. — June 4, 1912
Capt. Q. M. C., N. A., Camp A. A. Humphreys, Va.

SNELL, GEORGE H. — July 10, 1906
49 County St., Attleboro, Mass.

SOLOMON, GABRIEL ROBERTS — June 24, 1913
Cons. Engr., 1622 Candler Bldg., Atlanta, Ga.

SONDEREGGER, ARTHUR L. — June 10, 1911
Cons. Engr., 635 Central Bldg., Los Angeles, Cal.

SPALDING, GEORGE R. — Mch. 28, 1914
Chem. Hackensack Water Co., New Milford, N. J.

SPAULDING, W. J. — Nov. 1, 1914
Commissioner, Springfield, Ill.

SPEAR, WALTER E. — Jan. 12, 1915
Major U. S. R., Officer in Chge. of Utilities, Camp Upton, N. Y.

SPERRY, WALTER A. — Dec. 30, 1914
Chem. Filtn. Plant, Grand Rapids, Mich.

SPILLER, H. C. — Jnly 24, 1918
Prest. Jackson Wtr. Sup. Co., 27 State St., Boston, Mass.

SPIRE, LEONARD S. — July 24, 1918
Hyd. & Valve Recorder, Bur. Water, 50 Lakeview Ave., Buffalo, N. Y.

STAINTON, H. — Aug. 3, 1916
Waterworks Insp., Western Canada Fire Underwriters Assn., Box 2973, Winnipeg, Man.

STANFIELD, A. C., C.E. — Jan. 12, 1915
Pana, Ill.

STEARNS, HARRINGTON P. — Jan. 27, 1914
c/o Queens County Water Co., Far Rockaway, N. Y.

STEELE, J. A., JR. — Mch. 14, 1916
Mgr. City Water Wks., Vicksburg, Miss.

STEPHEN, CHARLES — Apr. 14, 1916
Lieut. Cmdg. R. N., Naval Royal, H. M. S. "Skate," London, Eng.

STERLING, JOE C. — June 24, 1903
Supt. Water Wks., Munroe, Mich.

Stevens, Harold C. Cons. Engr., 150 Nassau St., New York, N. Y.	May 12, 1914
Stevens, Harry Cons. Engr. Union Tr. Bldg., Washington, D. C.	May 13, 1916
Stone, E. W. Analyst, Pueblo Water Wks., Box 818, Pueblo, Col.	Oct. 9, 1916
Stone, R. D. Prest. & Mgr., 400 Chestnut St., Philadelphia, Pa.	Dec. 22, 1915
Storrie, William Ch. Engr., John ver Mehr Engineering Co., 154 Simcoe St., Toronto, Ont.	May 8, 1915
Stover, Frederick H. Crescent Hill Filter, Louisville, Ky.	June 4, 1912
Streeter, C. H. Supt. Water & Elect. Plants, Cedar Falls, Ia.	May 8, 1915
Streeter, H. W. San. Engr., U. S. Hyg. Lab., 25th & E Sts., Washington. D C.	May 8, 1915
Stromquist, W. G. U. S. Pub. Health Serv., 3d & Kilgour Sts., Cincinnati, Ohio.	Oct. 26, 1914
Strothman, L. E. Mgr. Pumping Eng. & Steam Turb. Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis.	Apr. 27, 1910
Sturges, Lee Prest. Elmhurst Spring Water Co., Elmhurst, Ill.	Mch. 4, 1915
Sullivan, C. J. Supt. Water Wks., 319 2d Avenue N., Chisholm, Minn.	June 24, 1913
Sumner, Guilford H., M.D. Secy. Iowa State Bd. of Health, Des Moines, Ia.	May 29, 1916
Surveyer, Arthur Cons. Engr., 274 Beaver Hall Hill, Montreal, Can.	Apr. 14, 1916
Suter, Russell, Capt. E. O R. C , Am. Exp Forces.	Oct. 16, 1914
Sweet, E. O., C.E. Birmingham Water Wks. Co., 1106½ Virginia Ave., Birmingham, Ala.	May 30, 1916
Switzer, John A. Cons. Engr., Prof. Hyd. & San. Engrg., Univ. of Tenn., Knoxville, Tenn.	May 14, 1916
Sylvester, Elbert W. City Engr. & Supt. Pub. Wks., Poughkeepsie, N. Y.	June 3, 1916

Symons, M. M. Ch. Engr. Interstate Water Co., 1009 W. Fairfield St., Danville, Ill.	Apr. 19, 1915
Taber, George A. Cons. Engr., Park Row Bldg., New York, N. Y.	June 4, 1912
Talbot, Arthur N. Prof. Municipal & San. Engrg., Univ. of Ill., Urbana, Ill.	Aug. 22, 1894
Talbott, Frank Supt., Secty., & Treas. Water Wks, Danville, Va.	June 7, 1904
Tanner, Fred W., Ph.D. Bact. Dept., 365 Chem. Bldg., Univ. of Ill., Urbana, Ill.	Nov. 1, 1914
Tarr, H. G. H. 400 Chestnut St., Philadelphia, Pa.	June 10, 1911
Taylor, Henry W. Hyd. & San. Eng., 26 Cortland St., New York, N. Y.	Jan. 27, 1914
Taylor, George R. San. Chem., 115 Wyoming Ave., Scranton, Pa.	May 12, 1908
Taylor, Samuel A. Cons. & Constr. Engr., 5th Floor, 2d Natl. Bk. Bldg., Pittsburgh, Pa.	June 10, 1902
Taylor, W. E. Ch. Engr. Water Co., Water St. & Big 4, Terre Haute, Ind.	July 18, 1903
Thayer, Frederick C. Prest. Kennebec Water Dist., Waterville, Me.	May 12, 1908
Thomas, D. G. Ch. Engr., The Denver Union Water Co., Denver, Colo.	June 8, 1909
Thomas, Robert J. Supt. Wtr. Wks., 85 11th St., Lowell, Mass.	May 16, 1900
Thompson, Charles N. Gen. Mgr. Bucks Hill Water Co., Bucks Hill Falls, Pa.	May 12, 1914
Thorne, Milton Supt. Portland Water Dist., 8 Lightfoot St., Portland, Me.	Apr. 14, 1916
Thornell, Joseph B. Chem. Broadway Pumping Sta., Council Bluffs, Iowa.	Oct. 16, 1916
Tighe, James L. Cons. Engr., 189 High St., Holyoke, Mass.	Apr. 17, 1889

TILDEN, JAMES A. — Apr. 17, 1889
Mech. Engr. Hersey Mfg. Co., Boston, Mass.

TISDALE, ELLIS S. — Oct. 18, 1916
Asst. Engr. San. Engrg. Div., State Dept. of Health, Charleston, W. Va.

TOAL, D. C. — June 24, 1903
Ed. *Water and Gas Review*, 35 Warren St., New York, N. Y.

TODD, WILLIAM — June 18, 1901
Supt. Elect. Lt. & Water Wks., Austin, Minn.

TOLLES, FRANK C. — Mch. 1, 1916
1st Lieut. Co. E., 112th Engrs., Am. Exp Forces.

TOLMAN, MAYO — Jan. 12, 1915
Dir. Div. of San. Engrg., W. Va. State Dept. of Health, Charleston, W. Va.

TOLSON, ALBERT — Jan. 28, 1916
Supt. of Filters, Bur. of Water, Philadelphia, Pa.

TOMLINSON, SAM — July 14, 1887
100 Robinson Rd., Singapore, S. S.

TOWNLEY, DAVID H. — May 30, 1916
Engr., Elizabethtown Water Co., 139 Murray St., Elizabeth, N. J.

TOWNSEND, E. R. — July 10, 1906
Hyd. Engr., 175 W. Jackson Blvd., Chicago, Ill.

TOYNE, J. W. — May 12, 1914
Capt. Q. M. C. Camp Custer, Mich.

TRAUTWINE, JOHN C., JR., C.E. — May 27, 1896
257 S. 4th St., Philadelphia, Pa.

TRAVIS, F. M. — July 30, 1917
Prest., The Torrington Water Co., 77 Church St., Torrington, Conn.

TRAX, E. C. — June 10, 1911
Chem., Filtn. Plant, McKeesport, Pa.

TREANOR, PAUL W. — Apr. 30, 1918
Comr. of Water Works, Nashville, Tenn.

TRETHOWAN, H. C. — May 12, 1915
Under Secty. for Water Supply, 56 James St., Perth, W. Australia.

TRIBUS, LOUIS LINCOLN, C.E. — May 12, 1906
15 Park Row, New York, N. Y.

TROW, LINDEN C. — June 4, 1912
Supt. Water Wks., Lake Forest, Ill.

Tuttle, Arthur S. — July 10, 1906
Asst. Ch. Engr. Bd. of Est. & Apport., Municipal Bldg., New York, N. Y.

Van Deusen, W. P. — Feb. 24, 1917
Bact. and Chem., Water Wks. Dept., 3510 Architect Ave., N. E., Minneapolis, Minn.

Van Gilder, L. — July 10, 1906
Engr. & Supt. Water Dept., City Hall, Atlantic City, N. J.

Van Loan, Seth M. — May 12, 1914
4334 Pine St., Philadelphia, Pa.

van Trump, S. N. — Feb. 8, 1916
Asst. Engr. & Supt. Water Wks., Wilmington, Del.

Vasconcellos, Joshua — May 3, 1916
Comnr. of Pub. Prop., City Hall, Jacksonville, Ill.

Veatch, Francis M. — Oct. 4, 1916
Asst. Engr., Kansas State Bd. of Health, Lawrence, Kan.

Veatch, N. T., Jr. — Dec. 20, 1915
Cons. Engr., 507 Inter-State Bldg., Kansas City, Mo.

Vermeule, Cornelius C., C.E. — June 8, 1909
203 Broadway, New York, N. Y.

Vest, W. E. — June 10, 1911
Supt. Water Wks., Charlotte, N. C.

Vinal, C. H. — June 24, 1913
Cons. Engr., 522 68th St., West Allis, Wis.

Volkhardt, William — June 11, 1902
15 Townsend Ave., Stapleton, N. Y.

Vrooman, Morrell — June 24, 1913
San. Engr., Gloversville, N. Y.

Wadsworth, G. A. — June 26, 1918
Supt. Water Dept., Evanston, Ill.

Wagenhals, Herbert H. — Aug. 24, 1915
U. S. Pub. Health Serv., 3d & Kilgour Sts., Cincinnati, Ohio.

Wagner, Bernard M. — Nov. 24, 1914
Cons. Engr., 11 Broadway, New York, N. Y.

Wagner, E. G. — Dec. 30, 1916
Supt. Water Wks. City Hall, Lewiston, Idaho.

Wagner, H. F. — May 12, 1914
Chem., Bur. of Water, Lab., Col. F. G. Ward Sta., Buffalo, N. Y.

WALDEN, A. E.
Supt. & Ch. Engr., 100 W. Fayette St., Baltimoı Md.

WALKER, ELTON D.
Capt. Co. A, 15th U. S. Engrs., Am. Exp. Forces.

WALL, EDWARD E.
Water Comnr., 312 City Hall, St. Louis, Mo.

WALLACE, ROBERT B.
Water Wks. Trustee, Council Bluffs, Ia.

WALRADT, ARTHUR E.
26 Liberty St., New York, N. Y.

WARDER, CHARLES
Supt. Water Wks., Niagara Falls, Ont.

WARDLE, ANDREW NELSON
Asst. Engr. Div. of San. Engrg., State Dept. Health, Charleston, W. Va.

WARDWELL, EVERETT C.
Trustee Kennebec Water Dist., Waterville, Me.

WARING, F. HOLMAN
Asst. Engr., Div. of San. Engrg., State Bd. Health, Columbus, O.

WARNER, G. H.
Supt. Water Wks., St. Petersburg, Fla.

WARNER, WILLIAM S.
Chem. and Bact., Hotel du Pont, City Point, Va.

WARREN, CHARLES E.
Trustee Kennebec Water Dist., Waterville, Me.

WATERMAN, FAY L.
Supt., 115 Jefferson Ave., Endicott, N. Y.

WATKINS, THOMAS
Mech. Engr., Johnstown, Pa.

WATTERS, GEORGE LAWRENCE
Hyd. Engr. Lehigh Valley R. R., So. Bethlehem, P

WEBSTER, DAVID LOUIS, M.E.
Brantford Water Co., 18 Leonard St., Brantfor Ont.

WEBSTER, EDWIN ROLAND
Cons. Engr., Webster Bldg., Chicago, Ill.

WEGMAN, EDWARD
Cons. Engr., Park Row Bldg., New York, N. Y.

WEHR, ALBERT H.
Prest. Baltimore County Water & Elect. Co., Bal timore, Md.

Welker, Joseph E. Asst. Engr., State Bd. of Health, University Club, Lawrence, Kan.	Jan. 24, 1916
Wells, George M. Cons. Engr., 40 Wall St., New York, N. Y.	June 24, 1913
Wells, J. N. Supt. Muncie Water Co., Muncie, Ind.	July 18, 1907
Werner, Ray C. Dir. Div. Wtr. Anal., State Bd. of Hlth., Atlanta, Ga.	June 24, 1918
West, Francis D. Chem. Torresdale, Philadelphia, Pa.	Feb. 24, 1914
West, Geo. F. Prest. Biddeford & Saco Water Co., Portland, Me.	June 4, 1912
West, George M. Supt., 168 First St., Lehighton, Pa.	Mch. 17, 1916
West, Vernon F. Lieut. U. S. Navy, Portland, Me.	June 25, 1914
West, Warren G. Supt. & Secty., The Leadville Wtr. Co., Leadville, Col.	Apr. 20, 1918
Weston, Robert Spurr Cons. San. Engr., 14 Beacon St., Boston, Mass.	June 15, 1896
Westover, George D. Genl. Mgr. Water & Lt. Co., Cadillac, Mich.	June 10, 1911
Wetter, Clarence H. Supt. Water Wks., Tiffin, Ohio.	July 27, 1915
Wheeler, Robert C., C.E. Capt. Q. M. C., Newport News, Va.	Oct. 23, 1914
Wheeler, Samuel Supt. Water Co., Ashland, Wis.	June 24, 1903
Wheeler, William Cons. C. E., 14 Beacon St., Boston, Mass.	July 10, 1906
Whipple, George C. Cons. Engr., Pierce Hall, Harvard Univ., Cambridge, Mass.	June 7, 1904
White, Gilbert C., C.E. Durham, N. C.	May 12, 1908
Whitlock, Augustus N. Front and Fulton Sts., Chester, Pa.	June 4, 1912
Whitman, Ezra B. Major O. R. C., Camp Meade, Md.	Apr. 27, 1910

WHITSIT, LAWRENCE C. City Engr., 110 California Ave., Highland Park, Mich.	May 10, 1917
WHITTAKER, H. A. Dir. Div. of Sanitn., State Bd. of Health, Minneapolis, Minn.	June 24, 1914
WICKHAM, JAMES T. Royal Engrs., British Army, London	Apr. 16, 1914
WIGHT, H. C. Genl. Supt., Div. of Water, Dayton, O.	May 14, 1915
WIGLEY, CHESTER G., C.E. c/o Wallace & Tiernan Co., 137 Centre St., New York, N. Y.	Apr. 27, 1910
WILCOX, FRANK L. Cons. Engr., Syndicate Tr. Bldg., St. Louis, Mo.	May 12, 1914
WILCOX, WILLIAM F. Supt. Central Water Wks., Ensley, Ala.	Apr. 27, 1910
WILES, C. W. Supt. Water Wks., Delaware, Ohio.	May 17, 1899
WILHELM, E. G. Secty.-Treas. Williamsport Water Co., Williamsport, Pa.	Feb. 24, 1917
WILHELM, GEORGE Ch. Engr. East Bay Water Co., Oakland, Cal.	June 24, 1913
WILL, CHARLES K. Supt. Water Wks., 118 S. Queen St., Lancaster, Pa.	Mch. 1, 1916
WILLARD, ERNEST C., C.E. Nortonia Hotel, Portland, Ore.	Oct. 23, 1914
WILLETT, J. F. 138 Wyoming Ave., Billings, Mont.	May 9, 1915
WILLIAMS, GARDNER S. Cons. Engs., Cornwell Bldg., Ann Arbor, Mich.	July 10, 1906
WILLIAMS, HOWARD L. Supt. Water Wks., Ludington, Mich.	Aug. 24, 1894
WILLIAMSON, CLIFF T. Chmn. Bd. Water Comnr., 2554 Houston Rd., Macon, Ga.	June 24, 1913
WILLSON, WILLIAM JAY Supt. Water Wks., Greenwich, Conn.	June 8, 1916
WILSON, EDGAR K. Prin. Asst. Engr., c/o The Pitometer Co., 25 Elm St., New York, N. Y.	June 24, 1913

WILSON, HORACE Prest. & Genl. Mgr., 404 S. Clayton St., Wilmington, Del.	May 12, 1914
WILSON, JAMES B. Ch. Engr. & Supt., Louisville Water Co., Louisville, Ky.	Apr. 14, 1915
WILSON, JESSE H., C. E., City Engineer, Idaho Falls, Idaho	June 26, 1918
WILSON, JOHN City Engr., Duluth, Minn.	Apr. 27, 1910
WINDHOLZ, CHARLES A. Supt. Bur. of Water, Syracuse, N. Y.	May 30, 1916
WINGFIELD, NISBET Cons. Engr., Augusta, Ga.	June 10, 1911
WINSLOW, C.-E. A. Yale Medical School, New Haven, Conn.	Apr. 21, 1915
WINSLOW, W. H. V.-Prest. & Genl. Mgr. Superior Water, Lt. & Power Co., Superior, Wis.	June 8, 1909
WOLBERT, H. E. Supt. N. Y. Inter-Urban Water Co., Mt. Vernon, N. Y.	May 30, 1916
WOLMAN, ABEL San. Engr., 16 West Saratoga St., Baltimore, Md.	Mch. 28, 1918
WOOD, EDWARD R., JR. Capt. 118th F. A., Am. Exp. Forces.	Apr. 4, 1916
WOOD, HENRY H. Supt. Water Works, City Hall, Muskogee, Okla.	June 26, 1918
WOOD, WALTER Prest. Millville Water Co., 400 Chestnut St., Philadelphia, Pa.	June 7, 1904
WOODBURN, WILLIAM F. 201 Devonshire St., Boston, Mass.	June 24, 1903
WOOLFOLK, HENRY E. Supt. Water Wks., Danville, Ky.	June 4, 1912
WORRELL, M. L. Capt. Q. M. C., Asst. Officer in Charge of Utilities, Camp Logan, Tex.	June 24, 1903
WORTHEN, JESSE M. San. Engr., Midland Park, S. C.	June 9, 1909
WRIGHT, JOHN BERTRAM, C.E. Capt. Co. C, 520th Engrs., Camp A. A. Humphrey, Va.	July 28, 1914

WYCKOFF, CHARLES RAPELYE, C. E., c/o Geo. A. Johnson, 150 Nassau St., New York, N. Y.	Apr. 4, 1918
WYNNE-ROBERTS, R. O. 40 Jarvis St., Toronto, Ont.	June 24, 1903
WYSE, F. C. Engr. & Supt. Sewers & Water Wks., Columbia, S. C.	June 10, 1910
YERBANCE, W. B. Cons. Engr. & Operator for Pub. Util., 128 Broadway, New York, N. Y.	June 4, 1912
YORK, EDWARD C. Ch. Engr. Pumping Stn. Water Wks., 3236 Portland Ave., Minneapolis, Minn.	May 9, 1917
YOUNG, A. A. Supt. Water Wks., Jewett City, Conn.	Oct. 23, 1914
YOUNG, C. C. Dir. State Water Survey, Lawrence, Kansas.	Jan. 27, 1914
YOUNG, WILLIAM R. Registrar Water Wks., City Hall, Minneapolis, Minn.	June 8, 1909
ZEHR, VRATISLAV ADOLPH Mech. Engr., P. O. Box 349, Quincy, Ill.	Apr. 20, 1918

CORPORATE MEMBERS

AGUA PURA COMPANY 701 Douglas Ave., East Las Vegas, N. M.	June 8, 1909
ALEXANDRIA WATER CO. Alexandria, Va.	June 8, 1909
AMERICAN WATER WORKS AND ELECTRIC COMPANY, INC. H. Hobart Porter, Prest., 50 Broad St., New York, N. Y.	June 28, 1915
AUBURN WATER DEPARTMENT Auburn, N. Y.	June 10, 1911
BATON ROUGE WATER WORKS COMPANY Baton Rouge, La.	Apr. 16, 1914
BIRMINGHAM WATER COMPANY Derby, Conn.	Oct. 16, 1914
BOARD OF FIRE AND WATER COMMISSIONERS City Hall, Kansas City, Mo.	Dec. 18, 1913
BOARD OF PUBLIC WORKS Water Dept., Court House, Boonville, Mo.	June 28, 1915
BOARD OF WATER COMMISSIONERS John Taylor, Chm., Wildwood, N. J.	June 8, 1916
BOARD OF WATER AND ELECTRIC LIGHT COMMISSIONERS Lansing, Mich.	May 13, 1916
BRANTFORD WATER COMMISSIONERS Brantford, Ont.	June 10, 1911
BUREAU OF SANITARY ENGINEERING State Bd. of Health, Bowling Green, Ky.	April 9, 1913
BUREAU OF WATER Mr. John K. Stauffer, Supt., City Hall, Reading, Pa.	Mch. 1, 1916
BUREAU OF WATER WORKS AND SUPPLY 645 S. Olive St., Los Angeles, Calif.	June 8, 1909
CANTON WATER WORKS Canton, Ill.	Oct. 16, 1914
CEDAR RAPIDS WATER COMMISSIONERS Cedar Rapids, Iowa.	June 24, 1916
CITIZENS LIGHT, HEAT AND POWER COMPANY Tracy, Minn.	Mch. 18, 1918

Citizens Water Supply Co. Elmhurst, Long Island, N. Y.	June 8, 1909
City of Amsterdam Dept. Pub. Wks., Amsterdam, N. Y.	June 8, 1909
City Water and Light Company Sault Ste. Marie, Ont.	June 8, 1909
Coffeyville Water Department Wm. Helmering, Comnr., Coffeyville, Kans.	June 26, 1918
Columbia Water and Light Company Columbia, Tenn.	May 10, 1914
Commissioner of Public Property Newport, Ky.	June 4, 1910
Commissioners of Public Works Charleston, S. C.	June 4, 1912
Corning Water Works Corning, N. Y.	June 24, 1913
Department of Public Property H. M. Oldefest, Comnr., Moline, Ill.	June 28, 1917
Department of Public Service Grand Rapids, Mich.	June 24, 1913
Department of Public Utilities Rm. 302, City Hall, Portland, Ore.	Dec. 17, 1917
Dover Water Commissioners Peter C. Buck, Prest., Dover, Morris Co., N. J.	June 26, 1918
Eagles Mere Water Company Eagles Mere, Pa.	Apr. 22, 1914
East Bay Water Company Oakland, Cal.	Mch. 24, 1916
East Orange Board of Water Commissioners East Orange, N. J.	June 8, 1909
Elmira Water Board Elmira, N. Y.	Apr. 19, 1915
Erie Commissioners Water Works City Hall, Erie, Pa.	June 10, 1911
Evansville Water Works Evansville, Ind.	June 8, 1909
Excelsior Springs Water, Gas and Electric Co. Excelsior Springs, Mo.	June 4, 1912
Galt Water Commission Galt, Ontario, Canada.	June 24, 1913

GREATER WINNIPEG WATER DISTRICT Mr. R. D. Waugh, Chm., Winnipeg, Man.	Mch. 28, 1914
HOPKINSVILLE WATER COMPANY Hopkinsville, Ky.	May 9, 1915
LACROSSE BOARD OF PUBLIC WORKS LaCrosse, Wis.	June 10, 1911
LAKE CHARLES RAILWAY, LIGHT AND WATER WORKS CO. Lake Charles, La.	Apr. 27, 1910
LORAIN WATER WORKS Lorain, Ohio.	Aug. 18, 1916
LOUISVILLE WATER CO. 549 Third St., Louisville, Ky.	June 8, 1909
MAHONING VALLEY WATER COMPANY, THE Jas. J. McNally, Secty. & Treas., Youngstown, Ohio.	June 8, 1909
MANHASSET-LAKEVILLE WATER DISTRICT Manhasset, N. Y.	Mch. 18, 1918
MARION WATER COMPANY, THE George Whysall, Supt., Marion, Ohio.	Mch. 3, 1917
MEMPHIS ARTESIAN WATER DEPARTMENT Memphis, Tenn.	June 8, 1909
METROPOLITAN BOARD WATER SUPPLY AND SEWAGE Sidney, Australia.	June 8, 1909
METROPOLITAN WATER DISTRICT Omaha, Neb.	June 24, 1916
MICHIGAN STATE BOARD OF HEALTH Lansing, Mich.	July 17, 1917
MILLVILLE WATER COMPANY Millville, N. J.	June 15, 1916
MOBILE CITY COMMISSIONERS Mobile, Ala.	June 10, 1911
MOUNT CARMEL WATER CO. Mount Carmel, Pa.	June 8, 1909
NEW ALBANY WATER WORKS New Albany, Ind.	Apr. 27, 1910
OWEGO WATER WORKS COMPANY Owego, N. Y.	Apr. 22, 1914
PENNICHUCK WATER WORKS 144 Main St., Nashua, N. H.	Oct. 31, 1914
PETERBOROUGH UTILITIES COMMISSION Waterworks Dept., 253 Hunter St., Peterborough, Ont., Can.	June 10, 1911

PINE BLUFF COMPANY, THE Minor Q. Woodward, Treasr., Pine Bluff, Ark.	May 12, 1908
PUBLIC SERVICE DEPARTMENT 575 Broadway, Glendale, Cal.	Dec. 30, 1914
PUBLIC UTILITIES COMMISSION London, Canada.	June 8, 1909
RENO POWER, LIGHT AND WATER COMPANY Reno, Nev.	June 24, 1913
ROCKFORD WATER DEPARTMENT Thomas H. Connors, Supt., Rockford, Ill.	May 12, 1916
SAGINAW WATER DEPT. Saginaw, Mich.	June 8, 1909
SAN JOSÉ WATER COMPANY San José, Cal.	June 24, 1913
SCRANTON GAS AND WATER CO. 115 Wyoming Ave., Scranton, Pa.	June 4, 1912
SIDNEY WATER WORKS COMPANY, THE Main St., Sidney, N. Y.	Feb. 24, 1917
SOUTH BEND WATER DEPARTMENT South Bend, Ind.	Apr. 9, 1915
SOUTH EASTON WATER CO. 102 S. 3d St., Easton, Pa.	June 4, 1912
ST. THOMAS WATER COMMISSIONERS St. Thomas, Ont.	June 8, 1909
STOCKTON WATER CO., THE 315 Market St., Camden, N. J.	Jan. 7, 1918
SUFFERN WATER COMMISSIONERS Suffern, N. Y.	June 10, 1911
SUPERINTENDENT WATER DIVISION Rm. 303, City Hall, Spokane, Wash.	June 4, 1912
SWEETWATER WATER CO. National City, Calif.	June 8, 1909
TEMPLE WATER WORKS Temple, Texas.	Apr. 27, 1910
TRAFFORD WATER CO. 201 Westinghouse Bldg., Pittsburgh, Pa.	June 8, 1909
TRENTON WATER WORKS Trenton, N. J.	June 8, 1909
UNITED LAND AND WATER COMPANY Deming, N. Mex.	June 26, 1918

Urban Water Supply Co. 60 Wall St., New York, N. Y.	June 4, 1912
Vinton-Roanoke Water Co. Francis W. Collins, Cons. Engr., 50 Church St., New York, N. Y.	June 8, 1909
Waco Water Works City Hall, Waco, Texas.	Apr. 27, 1910
Washington Power, Light and Water Company Anacortes, Wash.	June 8, 1909
Water and Light Board J. J. Rowan, Supt., 409 McKinley St., Hibbing, Minn.	Apr. 5, 1917
Water Works Department Anaconda Copper Mining Co., Anaconda, Mont.	Apr. 27, 1910
Waterloo Water and Light Commission Waterloo, Ont., Canada.	Apr. 9, 1915
Watertown Water Works Watertown, N. Y.	June 8, 1909
Western New York Water Company 704 Elect. Bldg., Buffalo, N. Y.	June 24, 1913
White Deer Mountain Water Company 114 S. Front St., Milton, Pa.	May 10, 1914
White Plains Department of Public Works Wm. H. Lyon, Comr. in charge of Water Wks., White Plains, N. Y.	Aug. 18, 1916
Williamsport Water Co. 330 Pine St., Williamsport, Pa.	June 8, 1909

ASSOCIATE MEMBERS

Addressograph Company 901 W. Van Buren St., Chicago, Ill.	June 10, 1906
Alberger Pump and Condenser Company 140 Cedar St., New York, N. Y.	June 10, 1911
Allis-Chalmers Manufacturing Company Milwaukee, Wis.	June 27, 1905
American Bitumastic Enamels Company 17 Battery Pl., New York, N. Y.	June 24, 1913
American Cast Iron Pipe Company Birmingham, Ala.	July 18, 1907
American City 87 Nassau St , New York, N. Y.	June 26, 1918
American Foundry and Manufacturing Company 10th, 11th, Hebertt & Wright Sts., St. Louis, Mo.	May 12, 1908
American Manganese Bronze Company Holmesburg, Philadelphia, Pa.	May 13, 1916
American Pipe and Construction Company 112 N. Broad St., Philadelphia, Pa.	June 24, 1913
American Spiral Pipe Works F. B. Sanborn, Eastern Sales Mgr., 50 Church St., New York, N. Y.	Aug. 18, 1916
American Steel and Wire Company 208 S. LaSalle St., Chicago, Ill.	June 24, 1903
Arnold, Hoffman and Company, Inc. P.O. Box 762, New York, N. Y.	Dec. 4, 1913
Badger Meter Manufacturing Company 261 Third St., Milwaukee, Wis.	June 8, 1904
Baldwin, Robert C. Sec'y & V. P., C. Lee Cook Mfg. Co., Inc., 916–930 S. Eighth St., Louisville, Ky.	May 14, 1914
Berg, J. D. V.-Prest. Dravo Doyle Co., Diamond Bank Bldg., Pittsburgh, Pa.	May 12, 1914
Birch-Hintz Manufacturing Company 1100–1110 S. Kilbourn Ave., Chicago, Ill.	May 12, 1914

Bourbon Copper and Brass Works Company 618 E. Front St., Cincinnati, Ohio.	Apr. 17, 1884
Boyd and Brother, Incorporated, James 25th and Wharton Sts., Philadelphia, Pa.	June 10, 1911
Bristol Company, The Waterbury, Conn.	June 13, 1916
Buffalo Meter Company 2917 Main St., Buffalo, N. Y.	June 27, 1905
Builders' Iron Foundry 9 Codding St., Providence, R. I.	June 18, 1901
Canadian Engineer, The Church and Court Sts., Toronto, Ont., Can.	June 26, 1918
Carbic Manufacturing Company West Duluth Stn., Duluth, Minn.	June 1, 1916
Central Brass Manufacturing Company, The 6203 Cedar Ave., Cleveland, O.	May 7, 1917
Central Foundry Company 90 West St., New York, N. Y.	June 24, 1903
Chapman Valve Manufacturing Company Indian Orchard, Mass.	Apr. 16, 1884
Chicago Bridge and Iron Company 37 W. Van Buren St., Chicago, Ill.	June 15, 1898
Clark Company, H. W. 115 S. 17th St., Mattoon, Ill.	May 12, 1908
Clow and Sons, J. B. Harrison and Franklin Sts., Chicago, Ill.	Apr. 27, 1885
Coldwell-Wilcox Company Newburgh, N. Y.	Apr. 16, 1914
Colorado Fuel and Iron Company Denver, Colo.	June 7, 1897
Columbian Iron Works Chattanooga, Tenn.	Apr. 27, 1910
Cook, A. D. Mnfr. Deep Well Pumps and Strainers, Lawrenceburg, Ind.	Feb. 17, 1915
Darling Pump and Manufacturing Company, The Williamsport, Pa.	May 12, 1908
DeLaval Steam Turbine Co. H. L. Watson, Sales Mgr., Trenton, N. J.	Nov. 23, 1917
Joseph Dixon Crucible Company Jersey City, N. J.	May 14, 1915

DONALDSON IRON CO. Emaus, Lehigh Co., Pa.	Nov. 23, 1917
DRESSER MANUFACTURING COMPANY, S. R. Mfr. Pipe Couplings and Sleeves, Bradford, Pa.	June 7, 1904
EAST JERSEY PIPE COMPANY, THE 50 Church St., New York, N. Y.	July 10, 1906
EDDY VALVE MANUFACTURING COMPANY Waterford, N. Y.	June 26, 1886
EIMER AND AMEND Third Ave., 18th to 19th Sts., New York, N. Y.	May 13, 1916
ELECTRO BLEACHING GAS COMPANY 18 East 41st St., New York, N. Y.	June 24, 1913
ENGINEERING NEWS-RECORD 10th Ave. at 36th St., New York, N. Y.	June 26, 1918
ENGINEERING AND CONTRACTING 608 S. Dearborn St., Chicago, Ill.	June 26, 1918
FARNAN BRASS WORKS COMPANY, THE 1104 Center St., Cleveland, Ohio.	May 18, 1892
FLOWER-STEPHENS MANUFACTURING COMPANY Detroit, Mich.	June 24, 1913
FORD METER BOX COMPANY Wabash, Ind.	May 12, 1908
FOX AND COMPANY, JOHN 253 Broadway, New York City, N. Y.	June 8, 1909
GAMON METER COMPANY Newark, N. J.	May 14, 1916
GARLOCK PACKING COMPANY Palmyra, N. Y.	May 12, 1908
GENERAL CHEMICAL COMPANY 112 W. Adams St., Chicago, Ill.	June 11, 1902
GILLESPIE, T. A. Prest. T. A. Gillespie Co., 50 Church St., New York, N. Y.	June 7, 1904
GLAMORGAN PIPE AND FOUNDRY COMPANY, THE Lynchburg, Va.	Apr. 27, 1910
GLAUBER BRASS MANUFACTURING COMPANY 4917 Superior Ave., Cleveland, Ohio.	June 7, 1904
GOULD, NORMAN J. Prest. The Goulds Mfg. Co., Seneca Falls, N. Y.	July 10, 1906
HARRISONS INC. 35th St. & Grays Ferry Rd., Philadelphia, Pa.	May 12, 1908

Hays Manufacturing Company Erie, Pa.	Mch. 15, 1882
Hersey Manufacturing Company South Boston, Mass.	July 14, 1887
International Filter Company 38 S. Dearborn St., Chicago, Ill.	May 9, 1915
Jareçki Chemical Company Cincinnati, Ohio.	June 8, 1909
Kalbfleisch Corporation 31 Union Square, W., New York, N. Y.	June 8, 1909
Kellogg and Company, E. H. 243 South St., New York, N. Y.	July 14, 1887
Kennedy Valve Manufacturing Company, The M. E. Kennedy, Treas., Elmira, N. Y.	May 25, 1895
Layne and Bowler Company Memphis, Tenn.	June 8, 1916
Lead Lined Iron Pipe Company, The Wakefield, Mass.	June 15, 1915
Leadite Company, Incorporated, The Land Title Bldg., Philadelphia, Pa.	Apr. 27, 1910
Lennig and Company, Incorporated, Charles Bridesburg, Philadelphia, Pa.	June 4, 1912
Linthicum, E. E. V.-Prest. Natl. Cast Iron Pipe Co., Birmingham, Ala.	May 17, 1916
Lock Joint Pipe Company Box 21, Ampere, N. J.	Oct. 26, 1915
Lockwood, H. S. Sales Agt., Sulphate Dept. Amer. Steel & Wire Co., 30 Church St., New York, N. Y.	May 11, 1917
Ludlow Valve Manufacturing Company Troy, N. Y.	Mch. 15, 1882
Lynchburg Foundry Company Lynchburg, Va.	June 13, 1916
McBride, Thomas C. Worthington Pump & Mach. Corp., North Amer. Bldg., Philadelphia, Pa.	Mch. 1, 1916
McGowan Company, John H., The 54-64 Central Ave., Cincinnati, Ohio.	June 24, 1916
McQuistan, Andrew Nisbet Ironfounder, Craigward, Busby, near Glasgow, Scotland.	Jan. 12, 1915

MARITIMO COATING CORPORATION Bayard N. Cole, Sales Mgr., 1733 Grand Central Terminal, New York, N. Y.	Feb. 27, 1917
MASSILLON IRON AND STEEL COMPANY, THE Massillon, O.	June 4, 1912
MODERN IRON WORKS Quincy, Ill.	June 27, 1905
MUELLER MANUFACTURING COMPANY, H. Decatur, Ill.	Mch. 15, 1882
MULTIPLEX MANUFACTURING COMPANY Berwick, Pa.	May 11, 1914
MUNICIPAL JOURNAL 24[illegible] West 39th St., New York, N. Y.	June 26, 1918
NATIONAL METER COMPANY 299 Broadway, New York, N. Y.	Mch. 15, 1882
NATIONAL WATER MAIN CLEANING COMPANY 50 Church St., New York, N. Y.	July 10, 1906
NEPTUNE METER COMPANY 50 E. 42d St., New York, N. Y.	Aug. 22, 1894
NEW YORK CONTINENTAL JEWELL FILTRATION COMPANY P. O. Box A., Nutley, N. J.	Apr. 18, 1891
NORWOOD ENGINEERING COMPANY Florence, Mass.	May 9, 1915
PACIFIC FLUSH TANK COMPANY 1415 Singer Bldg., New York, N. Y.	June 10, 1911
PARSONS CO., THE Newton, Iowa.	June 26, 1918
PENNSYLVANIA SALT MANUFACTURING COMPANY, THE Widener Bldg., Philadelphia, Pa.	June 24, 1908
PERMUTIT CO., THE 440 Fourth Ave., New York, N. Y.	Apr. 14, 1914
PITOMETER COMPANY, THE 25 Elm St., New York, N. Y.	July 10, 1906
PITTSBURG FILTER MANUFACTURING COMPANY Farmers Bk. Bldg., Pittsburgh, Pa.	June 27, 1905
PITTSBURGH METER COMPANY East Pittsburgh, Pa.	June 15, 1898
PITTSBURGH-DES MOINES STEEL COMPANY Pittsburgh, Pa.	Apr. 24, 1914
PLATT IRON WORKS COMPANY Dayton, Ohio.	June 18, 1901

PORTLAND CEMENT ASSOCIATION 111 W. Washington St., Chicago, Ill.	Oct. 31, 1917
PRATT & CADY COMPANY, INC. Lock Box 66, Stn. A, Hartford, Conn.	June 24, 1913
THE R. U. V. COMPANY 7 Burritt Ave., South Norwalk, Conn.	Feb. 11, 1917
RENSSELAER VALVE COMPANY Troy, N. Y.	May 21, 1890
ROBERTS, CHARLES V. Prest. Roberts Filter Mfg. Co., Darby, Philadelphia, Pa.	Apr. 27, 1910
ROSS VALVE MANUFACTURING COMPANY, INC. Oakwood Avenue, Troy, N. Y.	Apr. 18, 1891
S. E. T. VALVE AND HYDRANT COMPANY 50 Church St., New York, N. Y.	June 4, 1912
SANITARY COMPANY OF AMERICA, THE Linfield, Pa.	May 14, 1914
SANITATION CORPORATION 50 Church St., New York, N. Y.	May 9, 1915
SCHRAM & SON, CHRIS D. 308 N. 4th St., Philadelphia, Pa.	Apr. 3, 1917
SIMPLEX VALVE AND METER COMPANY 625 Wood St., Philadelphia, Pa.	May 12, 1914
SMITH MANUFACTURING COMPANY, ANTHONY P East Orange, N. J.	June 7, 1897
STANDARD ASPHALT AND REFINING CO. 205 La Salle St., Chicago, Ill.	May 12, 1908
STEWARTS AND LLOYDS 41 Oswald St., Glasgow, Scotland.	Feb. 11, 1917
SULLIVAN MACHINERY CO. 122 S. Michigan Ave., Chicago. Ill.	Apr. 23, 1915
TAYLOR COMPANY, W. P. 218 Ellicott Sq., Buffalo, N. Y.	Mch. 15, 1882
THOMSON METER COMPANY 100 Bridge St., Brooklyn, N. Y.	Apr. 15, 1891
UNION WATER METER COMPANY 33 Hermon St., Worcester, Mass.	Mch. 15, 1882
UNITED BRASS MANUFACTURING COMPANY Cleveland, Ohio.	May 11, 1914
UNITED LEAD COMPANY 111 Broadway, New York, N. Y.	May 12, 1908

UNITED STATES CAST IRON PIPE AND FOUNDRY COMPANY 1421 Chestnut St., Philadelphia, Pa.	June 11, 1892
UNITED STATES RUBBER CO. 1790 Broadway, New York, N. Y.	May 1 , 1918
WALLACE AND TIERNAN COMPANY 137 Centre St., New York, N. J.	May 9, 1915
WARREN FOUNDRY AND MACHINE COMPANY 11 Broadway, New York, N. Y.	June 10, 1911
WATER WORKS EQUIPMENT COMPANY Rms. 1950–51, 50 Church St., New York, N. Y.	July 10, 1916
WOLFF, S. Dist. Mgr., DeLaval Steam Turb. Co., 629 Peoples Gas Bldg., Chicago, Ill.	Apr. 9, 1915
WOOD AND COMPANY, R. D. 400 Chestnut St., Philadelphia, Pa.	Apr. 16, 1884
WOODS, FLOYD F. Sales Mgr. Epping Carpenter Pump Co., 1376 Montezuma St., Pittsburgh, Pa.	May 14, 1915
WORTHINGTON PUMP AND MACHINERY CORPORATION 115 Broadway, New York, N. Y.	June 18, 1901
WYCKOFF AND SON COMPANY, A. Elmira, N. Y.	July 18, 1907

GEOGRAPHICAL DISTRIBUTION OF MEMBERS

ALABAMA: Active 8; Corporate 1; Associate 2; Total 11

ACTIVE

BIRMINGHAM	Decker, A. C.
	Horner, H. H.
	Kirkpatrick, W. G.
	Sweet, E. O.
ENSLEY	Wilcox, W. F.
MONTGOMERY	Hazlehurst, G. H.
SELMA	Jones, J. W.
SHEFFIELD	Johnson, H. B.

CORPORATE

MOBILE..Mobile City Commissioners

ASSOCIATE

BIRMINGHAM	American Cast Iron Pipe Co.
	Linthicum, E. E

ARIZONA: Active 4; Total 4

ACTIVE

AJO	DuMoulin, W. L.
BISBEE	Shepard, J. A.
FLAGSTAFF	Giclas, E.
WINKELMAN	Grasty, E. C.

ARKANSAS: Corporate 1; Total 1

CORPORATE

PINE BLUFF.....Pine Bluff Co., The

CALIFORNIA: Active 28; Corporate 5; Honorary 1; Total 34

ACTIVE

BERKELEY	Bachman, F.
	Doman, J.
	Gillespie, C. G.
	Goudey, R.
	Hyde, C G.
	Klaus, F. J.
HANFORD	Isaacs, F. N.
LOS ANGELES	Dessery, F. C.
	Finkle, F. C.
	Hilscher, R.
	Lee, C. H.
	Sonderegger, A. L.
OAKLAND	Gilman, C. E.
	Wilhelm, G.
PACIFIC GROVE	Olmstead, C. S.
PASADENA	Allin, T. D.
SAN DIEGO	Ervast, A.
SAN FRANCISCO	Dockweiler, J. H.
	Elliott, G. A.
	Flaa, I. E.
	Hunter, T. B.
	Mohrhardt E. F.
	O'Shaughnessy, M. M.
	Pracy, G. W.
	Rice, P. D.
	Shibley, K.
SAN JOSÉ	Relph, O. S.
STOCKTON	Hall, J. W.

CORPORATE

Glendale...Public Service Department
Los Angeles..Bureau of Water Supply
National City..Sweetwater Water Co.
Oakland...........East Bay Water Co.
San José...........San José Water Co.

HONORARY

Berkeley...............LeConte, L. J.

COLORADO: Active 8; Associate 1; Total 9

ACTIVE

Brush..............Leerskov, A. D.
Colorado Springs,
McReynolds, B. B.
Denver............Catchpole, C. T.
Denver..........Robinson, W. P.; Thomas, D. G.
Leadville.............West, W. G.
Pueblo.............Porter, D. P.; Stone, E. W.

ASSOCIATE

Denver....Colorado Fuel & Iron Co.

CONNECTICUT: Active 21; Corporate 1; Associate 3; Honorary 1; Total 26

ACTIVE

Ansonia................Davis, F. J.
Bridgeport...........Senior, S. P.; Smith, G. Z.
Greenwich...........Willson, W. J.
Hartford........Berry, F. D.; Hinkley, R. L.; Howard, F. E.; Newlands, J. A.; Peck, E. M.; Saville, C. M.
Jewett City...........Young, A. A.
New Haven....Hill, A. B.; Mickle, F. L.; Minor, E. E.; Winslow, C.-E. A.
Rowayton..............Case, R. E.
Southington.......McKenzie, S. H.
Stamford..............Hatch, E. L.
Thompsonville......Schwabe, W. P.
Torrington...........Travis, F. M.
Waterbury........McDonald, C. E.

CORPORATE

Derby.......Birmingham Water Co.

ASSOCIATE

Hartford....Pratt & Cady Co. Inc.
South Norwalk........R. U. V. Co.
Waterbury.........Bristol Co., The

HONORARY

New Haven.............Holly, I. A.

DELAWARE: Active 6; Total 6

ACTIVE

Wilmington....Alexander, M.; Coxe, W. G.; Hilles, T. A.
Wilmington....Hoopes, E. M.; van Trump, S. N.; Wilson, H.

DISTRICT OF COLUMBIA: Active 8; Total 8

ACTIVE

Washington: Doten, L. S.; Gaub, John; Hardy, E. D.; Howell, D. J.
Washington: Phelps, E. B.; Rhynus, C. P.; Stevens, H.; Streeter, H. W.

FLORIDA: Active 8; Total 8

ACTIVE

Daytona........Main, G. A.
Jacksonville: Harrub, C. N.; Murphy, L. E.; Smoot, L. D.
Miami........Hyman, H. H.
Orlando........Cheney, J. Y.
St. Petersburg........Warner, G. H.
Tampa........McFarland, C. R.

GEORGIA: Active 13; Total 13

ACTIVE

Atlanta: Clayton, R. M.; Hazelhurst, J. N.; Rapp, W. M.; Smith, W. Z.; Solomon, G. R.; Werner, R. C.
Augusta........Wingfield, N.
Columbus........Chipley, D.
Commerce........Caston, D. L.
Jackson........Merck, W. E.
La Grange........Sargent, G. H.
Macon........Williamson, C. T
Savannah........Conant. E. R.

IDAHO: Active 2; Total 2

ACTIVE

Idaho Falls........Wilson, J. H.
Lewiston........Wagner, E. G.

ILLINOIS: Active 103; Corporate 3; Associate 15; Total 121

ACTIVE

Alton: Miller, J. A.; Parker, C. T.
Aurora: Barclay, W. E.; Leaf, C. E.; Miller, C.
Beardstown: Aldrich, A. C.; Angier, E. E.
Bloomington........Brown, C. C.
Cairo........Roos, C. M.
Carlinville........Castle, G. J.
Champagne........Amsbary, F. C.
Chicago: Alvord, J. W.; Bauereisen, R. J.; Bemis, E. W.; Burdick, C. B.; Converse, W. A.; Davidson, G. M.; DeBerard, W. W.; Ellis, G. R.; Ericson, J. E.; French, D. K.
Chicago: Gerber, W. D.; Green, P. E.; Hadden, S. C.; Hecht, J. L.; Howson, L. R.; Jennings, C. A.; Jordon, E. O.; Keeler, H. E.; Knowles, C. R.; Lucas, H. L.; McClenahan, W. T.; Maury, D. H.; Maxwell, D. H.; Mory, A. V. H.; Nichols, A. E.; Pearse, L.; Phillips, T. C.; Shaw, W. A.; Shields, W. S.; Townsend, E. R.; Webster, E. R.

DALLAS CITY............Zehr, V. A.
DANVILLE.......{Ely, H. M. / Symons, M. M.}
DECATUR..........{Lee, H. R. / Pownall, W. A.}
EAST ST. LOUIS...{Dutton, M. S. / Horner, C. M.}
EFFINGHAM.........Anderson, W. F.
ELGIN..................Kohn, C. L.
ELMHURST...............Sturges, L.
EVANSTON.......{Brower, I. C. / Wadsworth, G. A.}
FAIRBURY..............Burns, T. W.
FREEPORT..............Smith, O. T.
FULTON.................O'Rourke, J.
JACKSONVILLE........Vasconcellos, J.
JOLIET............O'Callahan, C. D.
KANKAKEE..............Cobb, C. H.
LAKE FOREST............Trow, L. C.
LINCOLN.............MacDonald, E.
MATTOON.............{Clark, H. W. / James, C. L. / Rue, J. A.}
MOLINE..............{Fritze, L. A. / Mellen, A. F.}
MT. CARMEL.............Barnard, P.
MT. VERNON.........Brandli, H. E.
OAK PARK...........Matte, H. P. T.
PANA...............Stanfield, A. C.
PEKIN..................Lautz, W. E.
PEORIA.............{Crozier, R. / Harman, J. A.}
PEORIA.............{Morgan, H. B. / Ringness, H.}
QUINCY...............Gelston, W. R.
ROCK ISLAND.........{Etzel, G. C. / Murrin, J. A}
SHELBYVILLE..........Chester, C. E.
SPRINGFIELD......{Bennett, C. G. / Drake, C. St.C. / Hansen, P. / Reid, W. / Sjoblom, M. C. / Spaulding, W. J.}
STREATOR..........{Huggans, D. E. / Huggans, R. D.}
TAYLORVILLE........Dappert, J. W.
URBANA........{Bartow, E. / Bennett, A. N. / Enger, M. L. / Ferguson, H. F. / Fleming, V. R. / Habermeyer, G. C. / Hatfield, W. D. / Newell, F. H. / Parr, S. W. / Schnellbach, J. F. / Talbot, A. N. / Tanner, F. W.}
WAUKEGAN.............Allen, W. J.
WINNETKA.............Greeley, S. A.

CORPORATE

CANTON........Canton Water Works.
MOLINE....Dept. of Public Property.
ROCKFORD.....Rockford Water Dept.

ASSOCIATE

CHICAGO.....{Addressograph Co. / Amer. Steel & Wire Co. / Birch-Hints Mfg. Co. / Chicago Bridge & Iron Co. / Clow & Sons, J. B. / Engineering & Contracting / General Chemical Co. / International Filter Co. / Portland Cement Association / Standard Asphalt and Refining Co. / Sullivan Mchy. Co. / Wolff, S.}
DECATUR...................Mueller Mfg. Co., H.
MATTOON.......................Clark Co., H. W.
QUINCY......................Modern Iron Works

INDIANA: Active 19; Corporate 3; Associate 2; Total 24

ACTIVE

Gary............Engle, S. G.; Luscombe, W.
Indianapolis......Brossman, C.; Garman, H. O.; Jordan, F. C.; Kirk, C. L.
Lafayette.............Miller, M. N.
LaPorte.............Harding, J. H.
Muncie.................Wells, J N.
Richmond................Dill, H. A.
Seymour...............Peter, W. F.
South Bend.........Ayres, T. H.; Luther, J. N.; Toyne, J. W.
Terre Haute......Gwinn, D. R.; Taylor, W. E.
Valparaiso...........Loomis, E. L.
Wabash................Klare, R. W.
Washington..........Semans, C. R.

CORPORATE

Evansville.....Evansville Water Works
New Albany..New Albany Water Works
South Bend....South Bend Water Dept.

ASSOCIATE

Lawrenceburg.............Cook Mfg. Co., A. D.
Wabash.....................Ford Meter Box Co.

IOWA: Active 42; Corporate 1; Associate 1. Total 44

ACTIVE

Ames.................Nichols, C. S.
Boone...............McCormick, R.
Burlington.......Lawlor, F. D. H.
Carroll...............Beiter, G. C.
Cedar Falls........Streeter, C. H.
Clinton................Chase, C. P.
Council Bluffs....Coppock, W.; Etnyre, S. L.; Jensen, J. C.; Thornell, J. B.; Wallace, R. B.
Creston..............Croxen, C. A.
Davenport.......Donahue, J. P.; Henderson, C. R.; Hooper, T. N.
Des Moines....Denman, C. S.; Evinger, M. I.; Higgins, L.; Kastberg, K. C.; Kinnaird, R. N.; Kirkpatrick, E. T.; Maffitt, D. L.; Sumner, G. H.
Dubuque...............Schwinn, P.
Ft. Dodge..............Pray, J. W.
Ft. Madison...............Kern, P.
Iowa City........Dunlap, J. H.; Hinman, J. J.; Hostetler, W. A.
Jefferson.................Gray, P.
Mason City...........Judd, W. A.
Missouri Valley Clinkenbeard. J. F.
Mt. Pleasant......McMillan, T. W.
Muscatine................Molis, W.
Oskaloosa...........Hawkins, H. C.
Ottumwa..............Brown, H. A.
Sioux City.........Carlin, P.; Gaynor, K. C.; Lewis, J. M.
Waterloo.......Berry, J. P.; Shoemaker, G. E.
Waukon...............Cowan, J. D.

CORPORATE

Cedar Rapids..........Cedar Rapids Water Commissioners

ASSOCIATE

Newton........Parsons Co., The

KANSAS: Active 11; Corporate, 1; Total 12

ACTIVE

Atchison............Chisham, J. M.
Chanute..................Pratt, C.
Emporia.................Smith, A. J.
Kansas City.......Chapman, L. H.
Lawrence.......... Haskins, C. A.; Veatch, F. M.
Lawrence.......... Young, C. C.; Welker, J. E.
Manhattan..........Conrad, L. E.
Topeka....................Shaw, J.
Wellington..........Mavity, J. W.

CORPORATE

Coffeville.Coffeyville Water Dept.

KENTUCKY: Active 17; Corporate 4; Associate 1; Total 22

ACTIVE

Ashland..............Patton, W. S.
Catlettsburg........Patton, W. A.
Danville...........Woolfolk, H. E.
Henderson..............Sieber, W.
Lebanon...............Rains, J. M.
Lexington..............Cramer, W. S.
Louisville..... Long, G. J.; Lovejoy, W. H.; McGonigale, W. J.
Louisville........... Potter, C. S.; Stover, F. H.; Wilson, J. B.
Middlesborough..McGiboney, J. H.
Newport...............Hornung, G.
Owensboro......Breidenbach, E. H.
Paducah.................Burnett, M.
Winchester.........Attersall, C. F.

CORPORATE

Bowling Green....Bureau of Sanitary Engineering
Hopkinsville..............Hopkinsville Water Co.
Louisville....................Louisville Water Co.
Newport.........Commissioners of Public Property

ASSOCIATE

Louisville....Cook Manufacturing Company, C. Lee, Inc.

LOUISIANA: Active 8; Corporate 2; Total 10

ACTIVE

Lake Charles........Landry, J. A.
New Orleans.... Earl, G. G.; Eastwood, J. T.; Fowler, E. A.
New Orleans.. Levy, A. G.; Middlemiss, G. A.
Shreveport.......... Kahn, L. I.; Amiss, T. L.

CORPORATE

Baton Rouge....................... Baton Rouge Water Works Co.
Lake Charles...Lake Charles Railway, Light and Water Works Co.

MAINE: Active 18; Total 18

ACTIVE

Bangor.............. Brown, W. I.; Powell, A. C.
Biddeford..............Burnie, A. N.
Brunswick............Bowker, C. L.
Fairfield........... Connor, V. R.; Nye, W. W.
Portland.......... Graham, J. W.; Newhall, W. G.; Payson, E. R.
Portland............. Thorne, M.; West, G. F.; West, V. F.
Waterville....... Boutelle, G. K.; Cook, H. J.; Hall, A. S.; Thayer, F. C.; Wardwell, E. C.; Warren, C. E.

MARYLAND: Active 16; Total 16

ACTIVE

City	Member
Baltimore	Adams, H.
	Armstrong, J. W.
	Baylis, J. R.
	Clemmitt, R. L.
	Hall, H. R.
	Jones, G. R.
	Morse, R. B.
	Powell, S. T.
Baltimore	Quick, A. M.
	Siems, V. B.
	Walden, A. E.
	Wehr, A. H.
	Whitman, E. B.
	Wolman, A.
Cumberland	Fowler, A. G.
Hagerstown	Heard, A.

MASSACHUSETTS: Active 37; Associate 5; Total 42

ACTIVE

City	Member
Attleboro	Snell, G. H.
Boston	Barbour, F. A.
	Foss, W. E.
	French, E. V.
	Fuller, F. L.
	Killam, S. E.
	Metcalf, L.
	Miller, H. A.
	Sherman, C. W.
	Spiller, H. C.
	Tilden, J. A.
	Weston, R. S.
	Wheeler, W.
	Woodburn, W. F.
Brockton	Kingman, H.
Brookline	Hale, R. K.
Cambridge	Whipple, G. C.
Concord	Robinson, L. C.
Dorchester	McInnes, F. A.
Florence	Ryan, W. G.
Holyoke	Gear, P.
	Tighe, J. L.
Lowell	Thomas, R. J.
Millbury	Mallalieu, W. C.
Natick	Adams, A. D.
New Bedford	Coggeshall, R. C. P.
North Andover	Bixby, M.
North Attleboro	Plattner, W.
Oxford	Wright, J. B.
Reading	Bancroft, L. M.
Southbridge	Abbott, G. H.
Springfield	Lochridge, E. E.
Wellesley	Hersey, F. C.
West Somerville	Babbitt, H. E.
	Lacount, H. O.
Williamstown	Mears, B.
Worcester	Batchelder, G. W.

ASSOCIATE

City	Member
Florence	Norwood Engineering Co.
Indian Orchard	Chapman Valve Mfg. Co.
South Boston	Hersey Mfg. Co.
Wakefield	Lead Lined Iron Pipe Co.
Worcester	Union Water Meter Co.

MICHIGAN: Active 27; Corporate 4; Associate 1; Total 32

ACTIVE

City	Member
Ann Arbor	Ayres, L. E.
	Hoad, W. C.
	Williams, G. S.
Bay City	Dawson, R. C.
Bessemer	Holley, C. R.
Cadillac	Westover, G. D.
Detroit	Clancy, L. J.
	Earl, R.
	Hubbell, C. W.
	Leisen, T. A.
	Mayo, W. B.
Escanaba	Hatton, W. J.
Flint	Baldwin, F. N.
	Buzzell, R. S.
Grand Rapids	Cummin, G. C
	Fitzpatrick, J. R
	Sperry, W. A.
Highland Park	Patterson, W. G.
	Whitsit, L. C.
Iron Mountain	Croll, E. A.
Jackson	England, R. G.
Luddington	Williams, H. L.
Manistee	Collins, F. W.
Marquette	Johnson, W. J.
Mt. Clemens	Keils, A.
Munroe	Sterling, J. C.
Saginaw	Eymer, H. H.

CORPORATE

Grand Rapids..............Department of Public Service
Lansing { Board of Water and Electric Light Commissioners; Michigan State Board of Health }
Saginaw.....................Saginaw Water Department

ASSOCIATE

Detroit.......................Flower-Stephens Mfg. Co.

MINNESOTA: Active 34; Corporate 2; Associate 1; Honorary 1; Total 38

ACTIVE

Austin.....................Todd, W.
Chisholm.............Sullivan, C. J.
Crookston.............Peterson, E.
Duluth.............. { Kelly, E. W.; Reed, D. A.; Wilson, John }
Eveleth.............Dorway, C. M.
Fergus Falls..........Leach, W. J.
Little Falls.........Gordon, T. C.
Mankato.........Blomquist, H. F.
Minneapolis..... { Bass, F. H.; Bernhagen, L. O.; Birdsall, L. I.; Calkins, W. N.; Cappelen, F. W.; Colehour, R. A.; Duncanson, A.V.; Jensen, J. A.; Johnson, E. W.; Jones, W. N.; Newell, C. W.; Van Deusen, W.P.; Whittaker, H. A.; York, E. C.; Young, W. R. }
Rochester...........Holmes, M. G.
St. Cloud................Seibert, J.
St. Paul...... { Childs, J. A.; Farnsworth, S. A.; Flanagan, J. C.; Goss, M. N.; House, G. O.; Keller, O. E. }
Virginia.............Harding, C. T

CORPORATE

Hibbing..Water and Light Board
Tracy.....Citizens Light, Heat and Power Co.

ASSOCIATE

Duluth... Carbic Manufacturing Co.

HONORARY

St. Paul...........Bement, R. C. B.

MISSISSIPPI: Active 6; Total 6

ACTIVE

Canton.................Sharp, J. T.
Hattiesburg.. ....Jones, B.
Meridian.............Worrell, M. L.
Senatobia...........Johnson, H. E.
Vicksburg...........Steele, J. A. Jr.
Yazoo City.............Butler, J. S.

MISSOURI: Active 29; Corporate 3; Associate 1; Honorary 1; Total 34

ACTIVE

HANNIBAL............Freiling, H. J.
INDEPENDENCE......Gallagher, H. A.
JEFFERSON City. Flad, E.; Landmann, L. B.
KANSAS CITY.... Anderson, J. F.; Archer, E. T.; Bardwell, R. C.; Black, E. B.; Burns, C. S.; McDonnell, R. E.; Veatch, N. T.
SEDALIA...............Andrews, L. P.
SPRINGFIELD.............Pate, R. L.
ST. LOUIS............ Allison, J. E.; Black, G. G.; Coult, F. H.; Cutts, F. T.; Day, L. A.; Daily, C. M.; Fuller, W. A.; Graf, A. V.; Henby, W. H.; Hollman, E. E.; Montfort, W. F.; Nolte, A. G.; Phillips, C. F.; Phillips, H.; Wall, E. E.; Wilcox, F. L.

CORPORATE

BOONVILLE..........Board of Public Works.
EXCELSIOR SPRINGS..Excelsior Springs Water Gas and Electricity Co
KANSAS CITY........Board of Fire and Water Commissioners.

ASSOCIATE

ST. LOUIS.....American Foundry & Manufacturing Co.

HONORARY

ST. LOUIS.....Holman, M. L.

MONTANA: Active 4; Corporate 1; Total 5

ACTIVE

BILLINGS...............Willett, J. F.
BOZEMAN............Cobleigh, W. M.
BUTTE....................Carroll, E.
MILES CITY............Pruett, G. C.

CORPORATE

ANACONDA.......Anaconda Copper Mining Co.

NEBRASKA: Active 6; Corporate 1; Total 7

ACTIVE

FLORENCE...............Jacobson, A.
LINCOLN...............Letton, H. P.
OMAHA .... Barr, W. M.; Jensen, M. A.; Larmon, F. P.; Prince, G. T.

CORPORATE

OMAHA.....Metropolitan Water District.

NEVADA: Active 2; Corporate 1; Total 3

ACTIVE

GOLDFIELD............Patrick, C. G.
RENO...............Campbell, G. A.

CORPORATE

RENO....Reno Power, Light & Water Co.

NEW HAMPSHIRE: Corporate 1; Total 1

CORPORATE

NASHUA....Pennichuck Water Works

NEW JERSEY: Active 65; Corporate 6; Associate 6; Total 77

ACTIVE

ATLANTIC CITY..... Decker, J. H.; Van Gilder, L.
BOONTON.............Breitzke, C. F.
BOUND BROOK....... Downes, J. R.; Smith, A. H.
BRIDGETON..........Fredrick, W. D.
BURLINGTON....... Conard, W. R.; Probasco, S. R.
CAMDEN............ Fithian, F. S.; Jones, W. C.; Long, J. H.
COLLINGSWOOD.......Borden, M. M.
EAST ORANGE........ Halpin, T. F.; Reimer, A. A.
ELIZABETH........ Booth, L. M.; Townley, D. H.
GLEN RIDGE...........Brooks, J. E.
HADDONFIELD...........Smith, E. H.
HOBOKEN............Anderson, R. M.
JAMESBURG........Foersterling, H..
JERSEY CITY... Corbin, C. K.; Fischer, C. H.; Griffin, J. W.; Henry, E. W.; LaTourrette, F.; McLaughlin, G. E.
LEONIA...............Buswell, A. M.
LITTLE FALLS..........Green, F. W.
MERCHANTVILLE....Rudderow, M. B.
MOORESTOWN.............Bishop, W.
MORRISTOWN...........Pitney, F. V.
NEW BRUNSWICK... Jones, A. J.; Morris, C. H.
NEW MILFORD.......Spalding, G. R.
NEWARK......... Denman, A. R.; Rosentretter, H.; Sanzenbacher, G.; Scholz, R. O.; Sherrerd, M. R.
NUTLEY........... Milligan, R. E.; Pratt, G. H.
PASSAIC................Hopper, W. C.
PATERSON....... Cook, J. H.; Cuddeback, A. W.; Edwards, W. R.
PERTH AMBOY......... Grieve, T.; Mason, S. J.
PHILLIPSBURG............Corr, A. S.
PLAINFIELD..............Gavett, W.
PLEASANTVILLE...........Herr, J. O.
PRINCETON.......... Eldridge, H. D.
RAHWAY.............Simonds, F. W.
RIVERTON................Buck, W. H.
ROSELLE PARK.........Crane, A. M.
SUMMIT............. Bassett, C. P.; Green, F.; Kimball, F. C.; McMane, W. I.
TRENTON.............Daggett, F. W.
UPPER MONTCLAIR....Goodell, J. M.
VINELAND.................Powers, J..
WEEHAWKEN...... French, D. W.; Miller, E. E.; Parker, C. B.
WOODBRIDGE.............Mundy, A.

CORPORATE

CAMDEN...........................Stockton Water Co., The
DOVER................................Dover Water Comnrs.
EAST ORANGE................Board of Water Commissioners.
MILLVILLE.......................Millville Water Company.
TRENTON.............................Trenton Water Works.
WILDWOOD..................Board of Water Commissioners.

ASSOCIATE

AMPERE................ Lock Joint Pipe Co.
EAST ORANGE.........Smith Mfg. Co., A. P.
JERSEY CITY.............Dixon Crucible Co.
NEWARK..................Gamon Meter Co.
NUTLEY.........N. Y. Cont. Jewell Filt. Co.
TRENTON.......DeLaval Steam Turbine Co.

NEW MEXICO: Corporate 2; Total 2

CORPORATE

DEMING ....United Land & Water Co.
EAST LAS VEGAS.......Agua Pura Co.

NEW YORK: Active 181; Corporate 14; Associate 43; Total 238

ACTIVE

ALBANY: Greenalch, W.; Horton, R. E.; Horton, T.; Schwartz, F. W.; Sherman, R. W.; Suter, R.
AMSTERDAM.............. Dwyer, C.
AUBURN............Ackerman, J. W.
AVON..................Clark, W. H.
BAY SHORE (L. I.).......Sands, C. G.
BELLMORE (L. I.): Bowne, W. E.; Johnson, P.
BROCKPORT................Ross, C. H.
BROOKLYN: Aeryns, A. N.; Hale, F. E.; Hendrick, W. M.; Lott, E. H.; Metcalf, J. T.
BUFFALO: Andrews, G. C.; Bassett, G. B.; Huy, H. F.; Spire, L. S.; Wagner, H. F.
CAMP UPTON......Armstrong, R. W.
CEDARHURST.............Lord, F. B.
CORNING..............Drake, W. O.
CORTLAND................Ott, E. W.
DOUGLASTON..........Brooks, J. N.
EAST ROCHESTER.....Babcock, G. H.
ELMHURST (L. I.)...Budelman, G. A.
ELMIRA..................Jones, H. F.
ENDICOTT...........Waterman, F. L
FAR ROCKAWAY: Bettes, C. R.; Durland, S. N.; Stearns, H. P.
GENESEO..............Meeker, G. R.
GLOVERSVILLE: Orr, A.; Vrooman, M.
HERKIMER............Sluyter, E. W.
HUDSON...............Longley, F. J.
HUNTINGTON............Irwin, T. E.
ITHACA...............Chamot, E. M.
JAMESTOWN..........Hapgood, L. P.
KINGSTON............ Harrison, J. H.
LONG BEACH......Carstein, L. W. F.
LONG ISLAND CITY...Bleistein, B. J.
MERRICK...............Spear, W. E.
MT. KISCO..............Sawin, L. R.
MT. VERNON: Tolles, F. C.; Wolbert, H. E.
NEW ROCHELLE.......Kemble, F. T.

NEW YORK: Andrews, R. E.; Applebaum, S. B.; Baker, M. N.; Baldwin, H. deF.; Barnes, T. H.; Beyer, A. H.; Biggs, G. W.,; Blossom, F.; Bogart, J.; Bowles, J. T. B.; Brightman, H. I.; Brown, R. H.; Brush, W. W.; Bull, I. C.; Buttennheim, H. S.; Calvo, A. R.; Cleverdon, W. S. L.; Cole, E. S.; Corbin, H. K.; Coulter, W. S.; Dennett, R. C.; deVarona, I. M.; Diven, J. M., Jr.; Donaldson, W.; Donnelly, R. J.; Drew, J. A.; Duggan, T. R.; Dunham, H. F.; Everett, C. M.; Ferguson, S. F.; Flinn, A. D.; Folwell, A. P.; Fuertes, J. H.; Fuller, G. W.; Goldsmith, C.; Gould, J. W. DuB.; Gregory, J. H.; Griswold, F. M.; Gubelman, F. J.; Hammer, E. W.; Hansen, A. E.; Hazen, A.; Hering, R.; Hill, N. S., Jr.; Hoagland, I. G.; Hodgman, B. B.; Hoffmaster, G. E.; Hone, F. deP.; Hulett, M.; Jackson, D. D.; Johnson, G. A.; Kienle, J. A.

New York:
Kilpatrick, J. D.
Klingberg, W.
Knox, S. K.
Kriegsheim, H.
Ledden, E. M.
Lobo, C.
Longley, F. F.
McCarthy, D. B.
McClintock, J. R.
McKim, R. A.
Machen, H. B.
Manahan, E. G.
Nelson, F. B.
O'Meara, R. J.
Orchard, W. J.
Pirnie, M.
Potter, A.
Potts, C.
Provost, A. J.
Purdy, J. H.
Rector, F. L.
Rider, J. B.
Rodman, G. E.
Shepperd, F. W.
Smith, J. W.
Smith, M. H.
Stevens, H. C.
Taber, G. A.
Taylor, H. W.
Toal, D. C.
Tribus, L. L.
Tuttle, A. S.
Vermeule, C.
Wagner, B. M.
Walradt, A. E.
Wells, G. M.
Wigley, C. G.
Wilson, E. K.
Wyckoff, C. R.
Yereance, W. B.

NEWARK..................Scarth, S.

NEWBURGH....
NORWICH......
OGDENSBURG...
OSSINING......
POUGHKEEPSIE.
PURDY STATION
ROCHESTER....
ROME..........
STAPLETON.....
SYRACUSE .....
TARRYTOWN...
TROY..........
TUPPER LAKE.
UTICA.........
WATERFORD...
WATERVLIET..
WOODHAVEN..
YONKERS.....

CORPORATE

AMSTERDAM................Department P
AUBURN.........................Auburn
BUFFALO................Western New Yor
CORNING.........................Corning W
ELMHURST................Citizens Water
ELMIRA............................Elmira
MANHASSET..........Manhasset-Lakeville
NEW YORK...... American Water Works
Urban Water Supply C
OWEGO........................Owego Wate
SIDNEY........................Sidney Wat
SUFFERN................Suffern Water Co
WATERTOWN..................Watertown
WHITE PLAINS..............Department I

ASSOCIATE

Brooklyn	Thomson Meter Co.
Buffalo	Buffalo Meter Co. Taylor Co., W. P.
Elmira	Kennedy Valve Mfg. Co , The Wyckoff & Sons Co., A.
New York	Alberger Pump Co. American Bitumastic Enamels Co. American City American Spiral Pipe Works Arnold, Hoffman & Co. Central Foundry Co. East Jersey Pipe Co., The Electro Bleaching Gas Co. Eimer & Amend Engineering News-Record Fox & Co., John Gillespie, T. A Kalbfleisch Corporation Kellogg & Co., E. H. Lockwood, H. S. Maritimo Coating Corp. Municipal Journal National Meter Co. National Water Main Cleaning Co. Neptune Meter Co. Pacific Flush Tank Co. Permutit Co., The Pitometer Co., The Sanitation Corporation S. E. T. Valve & Hydrant Co. United Lead Co. United States Rubber Co. Wallace & Tiernan Co. Warren Foundry & Machine Co. Water Works Equipment Co. Worthington Pump & Machinery Co.
Newburgh	Coldwell-Wilcox Co.
Palmyra	Garlock Packing Co.
Seneca Falls	Gould, Norman J.
Troy	Ludlow Valve Mfg. Co. Rensselaer Valve Co. Ross Valve Mfg. Co., Inc.
Waterford	Eddy Valve Mfg. Co.

NORTH CAROLINA: Active 16; Total 16

ACTIVE

Charlotte	Christie, J. G. C. Goentner, W. B. Vest, W. E.
Concord	Fisher, L. A.
Durham	Michie, J. C. White, G. C.
Eagle Springs	Maurice, G. H.
Elizabeth City	Lewis, R. E.
Goldsboro	Grantham, C. M.
Greensboro	Foushee, J. G.
Greenville	Allen, H. L.
Raleigh	Bain, E. B. Booker, W. H.
Salisbury	Neave, J. W.
Wilmington	Catlett, G. F.
Winston-Salem	Ludlow, J. L.

NORTH DAKOTA: Active 5; Honorary, 1: Total 6

ACTIVE

BISMARCK............Atkinson, T. R.
FARGO........... { Anders, F. L. / Blakemore, R. B.
GRAFTON...............Smith, K. H.
GRAND FORKS...........Smith, J. J.

HONORARY

BISMARCK...............Caulfield, J.

OHIO: Active 44; Corporate 3; Associate 9; Total 56

ACTIVE

BARNESVILLE..........Hobbs, R. A.
CHILLICOTHE...........Poland, J. A.
CINCINNATI..... { Bitgood, F. C. / Boeh, W. H. / Hauser, S. J. / Hill, J. W. / Miller, C. N. / Pollard, S. G. / Stromquist, W. G. / Wagenhals, H. H.
CLEVELAND...... { Beardsley, J. C. / Dusinberre, G. B. / Quayle, LeR. A. / Schulz, C. F.
COLUMBUS....... { Bair, M. Z. / Burgess, P. / Dittoe, W. H. / Eno, F. H. / Hoover, C. P. / McAlpine, A. H. / Martin, J. C. / O'Shaughnessy, J. / Richards, A.
COLUMBUS..... { Roberts, E. I. / Waring, F. H.
DAYTON............. { Barlow, J. E. / Wight, H. C.
DELAWARE..............Wiles, C. W.
DENNISON.............Romig, C. O.
FREEMONT.............Mohler, B. M.
IRONTON..........Heffelfinger, J. M.
KENT..................Messer, S. F.
LONDON................Fisher, E. P.
LORAIN.................Brown, C. A.
MANSFIELD..........McGinty, J. H.
MASSILLON.............Inman, A. W.
SHELBY...............Bricker, R. P.
SIMONS..................Britton, G.
TIFFIN................Wetter, C. H.
TOLEDO........... { Brown, C. S. / Champe, G. / Sherman, W. J.
WELLINGTON.........Gadfield, C. E.
XENIA.................Cooper, G. F.

CORPORATE

LORAIN......................Lorain Water Works
MARION...................Marion Water Co., The
YOUNGSTOWN....Mahoning Valley Water Co., The

ASSOCIATE

CINCINNATI.. { Bourbon Copper & Brass Works Co. / Jarecki Chemical Co. / McGowan Co., The John
CLEVELAND........ { Central Brass Mfg. Co., The / Farnan Brass Works Co., The / Glauber Brass Mfg. Co. / United Brass Mfg. Co.
DAYTON.....................Platt Iron Works Co.
MASSILLON........Massillon Iron & Steel Co., The

OKLAHOMA: Active 2; Total 2

ACTIVE

BARTLESVILLE...........Brua, E. G.
MUSKOGEE.............Wood, H. H.

OREGON: Active 3; Corporate 1; Total 4

ACTIVE

HILLSBORO..............Gates, H. V.

PORTLAND.......... Clarke, D. D.; Willard, E. C.

CORPORATE

PORTLAND.................Dept. of Public Utilities

PENNSYLVANIA: Active 107; Corporate 9; Associate 24; Total 140

ACTIVE

ALTOONA...........Campbell, C. B.
AMBLER...............Devine, W. J.
ASPINWALL.............Drake, C. F.
BALA.............Ramsey, W. H. C.
BERWICK................Hicks, J. S.
BROOKVILLE............Sayer, F. D.
BUCKS HILL FALLS, Thompson, C. N.
CARLISLE..................Faller, C.
CHAMBERSBURG......McGrath, F. R.
CHESTER.......... Whitlock, A. N.; Champion, R. B.
CLEARFIELD...........Nevling, J. B.
COLUMBIA.............Meyers, A. H.
CORRY.................Brown, R. W.
DARBY.............. Krieger, A. A.; Klein, W. I.
DOYLESTOWN.............Bishop, W.
EAST PITTSBURGH.....Holmes, A. G.
EASTON.................Rader, R. P.
ERIE............ Dunwoody, J. H.; Humphrey, E. W.
FLORIN................Nissly, E. L.
GERMANTOWN...........Corin, M. F.
GREENSBURG........... Smith, L. B.
HARRISBURG....... Crane, J. L.; Emerson, C. A.; Knisely, J. H.; Schaup, C. E.
JOHNSTOWN........ Crichton, A. B.; Watkins, T.
LANCASTER............ Shaw, F. H.; Will, C. K.
LEHIGHTON.............West, G. M.
LEWISTON.............Cooper, S. W.
MCKEESPORT............Trax, E. C.
MEADVILLE.......... Ellsworth, H.; Irwin, R. E.
MONESSEN..........McCabe, H. D.
MONONGAHELA.......... Nutt, J. A.
MOUNT UNION.........Bergan, P. H.
NORRISTOWN..........Jackson, R. A.
NORTH EAST............Leet, J. N.
PHILADELPHIA.. Bartlett, N. E.; Bean, G. L.; Birkenbine, C. P.; Boardman, W. H.; Buerger, C. B.
PHILADELPHIA.... Davis, C. E.; Dunlap, F. C.; Durst, J. A.; Grayson, T. J.; Gushee, E. G.; Keen, H. P.; Kneen, A. H.; Ledoux, J. W.; Lightfoot, J. C.; Manz, L. C.; Miller, C. F.; Nichol, E. M.; Quinn, M. P.; Russell, N. F. S.; Siddons, J. S. V.; Stone, R. D.; Tarr, H. G. H.; Tolson, A.; Trautwine, J. C.; Van Loan, S. M.; West, F. D.; Wheeler, R. C.; Wood, E. R., Jr.; Wood, W.
PITTSBURGH....... Baton, W. U. C.; Chester, J. N.; Handy, J. O.; Hopkins, N. F.; Hudson, L.; Knowles, M.; Leopold, F. B.; Mellon, T. A.; Rees, S. P.; Scharff, M. R.; Shepherd, A. B.; Taylor, S. A.
POTTSVILLE...........Pollard, W. D.
READING.......... Felix, G. H.; Heller, F. P.; Nuebling, E. L.
SCRANTON........... Cox, H. F.; Taylor, G. R.
SHAMOKIN.........McWilliams, C. Q.
SOUTH BETHLEHEM....Watters, G. L.
STATE COLLEGE.... Sackett, R. L.; Walker, E. D.
SUNBURY...........Rohrbach, W. R.

VERONA................Moore, G. H.
WASHINGTON.............Donnan, A.
WAYNE..................Pugh, M. R.
WILKES-BARRE....... Lance, J. H.; Lance, O. M.
WILKINSBURG....... Fox, C. L.; Hawley, W. C.

WILLIAMSPOI

WOMELSDORI

YORK.......

CORPORATE

EAGLES MERE..........................Eagle
EASTON.............................South E
ERIE.....................Erie Commissioner
MILTON......................White Deer Mou
MOUNT CARMEL.....................Mount C
PITTSBURGH.............................T
READING..................................
SCRANTON.........................Scranton
WILLIAMSPORT.......................Willia

ASSOCIATE

BERWICK.................................M
BRADFORD.............................Dress
EAST PITTSBURGH.......................Pitt
EMAUS..................................Dc
ERIE......................................
LINFIELD......................Sanitary Co.
PHILADELPHIA... American Manganese Bronz; American Pipe & Construct; Boyd & Bro., James; Harrisons, Incorporated; Leadite Co., The; Lennig & Co., Charles; McBride, T. C.; Pennsylvania Salt Mfg. Co.; Roberts, C. V.; Schram & Son, Chris. D.; Simplex Valve & Meter Co.; United States Cast Iron Pip; Wood & Co., R. D.
PITTSBURGH................ Berg, J. D.; Pittsburgh Fil; Pittsburgh-De; Woods, Floyd
WILLIAMSPORT................Darling Pump

RHODE ISLAND: Active 2; Associate 1; Total 3

ACTIVE

BRISTOL................. Jones, J
PROVIDENCE ....Smith, C

ASSOCIATE

PROVIDENCE..Builders' Iron Fou

SOUTH CAROLINA: Active 7; Corporate 1; Total

ACTIVE

COLUMBIA...............Wyse, F. C.
GREENWOOD..........Cothran, T. W.
MIDLAND PARK.......Worthen, J. M.

SPARTANBUR

UNION.......

CORPORATE

CHARLESTON..........Comnrs. of Pub

SOUTH DAKOTA: Active 2; Total 2

ACTIVE

Rapid City.......... Mangold, J. F.
Sioux Falls...........Connor, F. J.

TENNESSEE: Active 13; Corporate 2; Associate 2; Total 17

ACTIVE

Chattanooga........Lofton, H. M.
Dyersburg.........Blakeman, S. R.
Etowah................Price, W. H.
Fountain City.......Murphy, A. R.
Jackson...............Harris, H. M.
Knoxville...........Switzer, J. A.
Maryville...........Huston, R. C.
Memphis..............Layne, M. E.
Nashville.......... Ahearn, J. T.; Bulkley, O. E.; Elliott, R.; Reyer, G.; Treanor, P. W.

CORPORATE

Columbia.....Columbia Light & Water Co.
Memphis...Memphis Artesian Water Dept.

ASSOCIATE

Chattanooga....Columbian Iron Works
Memphis...........Layne & Bowler Co.

TEXAS: Active 6; Corporate 2; Honorary 1; Total 9

ACTIVE

Dallas.......... Elrod, H. E.; Hardgrave, A.; Rosenthal, H.
Fort Worth...........Eldredge, G.
San Antonio.........Harding, R. J.
Waco.................Martin, A. M.

CORPORATE

Temple........Temple Water Works
Waco............Waco Water Works

HONORARY

Galveston..........Cameron, W. L.

UTAH: Active 1; Total 1

ACTIVE

Salt Lake City......Barrett, C. F.

VERMONT: Active 2; Total 2

ACTIVE

Bennington............Ayres, J. H.
Burlington.............Moat, C. P.

VIRGINIA: Active 16; Corporate 2; Associate 2; Total 20

ACTIVE

Charlottesville......Carter, C. D.
City Point...... Boyle, E. C.; Showell, E. B. Jr.; Warner, W. S.
Danville.................Talbott, F.
Fredericksburg....Goodrick, E. H.
Lynchburg...........Perrow, M. G.
Newport News.. Livezey, W. B.; Manville, F. D.
Norfolk..............Bliven, C. H.
Petersburg........ Bunting, P. G.; Daniels, F. E.
Richmond........ Bolling, C. E.; Claiborne, H. A.; Davis, E. E.; Messer, R.

CORPORATE

ALEXANDRIA..................Alexandria Water Co.
ROANOKE................Vinton-Roanoke Water Co.

ASSOCIATE

LYNCHBURG... { Glamorgan Pipe & Foundry Co., Lynchburg Foundry Co.

WASHINGTON: Active 6; Corporate 2; Total 8

ACTIVE

CHELAN...............Harper, L. V.
HOQUIAM...........Heermans, H. C.
SPOKANE................Harding, G.
TACOMA........... { Everette, W. E. Roberts, W. J.
VAN COUVER BARRACKS ......McRae, H. C.

CORPORATE

ANACORTES...Washington Power, Light and Water Co.
SPOKANE..............Superintendent Water Division

WEST VIRGINIA: Active 7; Total 7

ACTIVE

BLUEFIELD............McCarthy, W.
CHARLESTON...... { Davisson, W. C. Tisdale, E. S. Tolman, M.
CHARLESTON..........Wardle, A. N.
CLARKSBURG.........Highland, S. G.
MOUNDSVILLE............Hetzer, M.

WISCONSIN: Active 24; Corporate 1; Associate 2; Total 27

ACTIVE

ASHLAND.................Wheeler, S.
BELOIT.............. { Lyons, B. F. Salmon, C. B.
GREEN BAY............Flatley, J. P.
KENOSHA.............Brennan, B. C.
MADISON............ { Bascom, G. R. Mead, D. W. Miller, W. E. Smith, L. A.
MILWAUKEE.... { Benzenberg, G. H. Bohmann, H. P. Engh, H. M.
MILWAUKEE.... { Ferebee, J. L. Hatton, T. C. Murphy, F. J. Sando, W. J. Strothman, L. E.
MONROE............ Gettings, M. T
PORT EDWARDS...Gochnauer, H. W.
SOUTH MILWAUKEE.....Neary, J. H.
SUPERIOR........ { Lounsbury, W. C. Winslow, W. H.
WAUKESHAW..........Hayford, B. B.
WEST ALLIS.............Vinal, C. H.

CORPORATE

LACROSSE....LaCrosse Board of Public Works

ASSOCIATE

MILWAUKEE. { Allis-Chalmers Mfg. Co. Badger Meter Mfg. Co.

WYOMING: Active 2; Total 2

ACTIVE

Cheyenne............Carlisle, C. C.
Rock Springs.............Bell, D. V.

CANADA: Active 53; Corporate 8; Associate, 1; Total 62

ACTIVE

Brandon, Man.........Shaw, A. W.
Brantford, Ont.... Frank, F. W.; Webster, D. L.
Brockville...........Bryson, G. H.
Edmonton, Alta.......Owens, R. B.
Kitchener, Ont..... Hymmen, H.; Michel, B. G.
Lindsay, Ont.....Hammond, W. H.
London, Ont....... Hodkinson, T.; Moore, J. M.
Merriton, Ont............Clark, R.
Montreal...... Francis, W. J.; Hunter, H. G.; Laberge, F. C.; Lafreniere, T. J.; Lea, R. S.; Leclerc, P.; Lesage, R.; Lesage, T. W.; McCrady, MacH.; Mercier, P.-E.; Perry, W.; Pitcher, F. H.; Plamondon, A.; Ross, R. A.; Surveyor, A.
Moose Jaw, Sask.....Mackie, G. D.
Niagara Falls, Ont.....Warder, C.
Ottawa........ McRae, J. B.; MacDonald, W. E.; Race, J.
Perth, Ont.............Smith, R. J.
St. Catharines...........Milne, A.
Ste. Anne de Bellevue..Stephen, C.
Toronto.... Angus, R. W.; Chipman, W.; Conway, G. R. G.; Dallyn, F. A.; Fellows, C. L.; Gaby, F. A.; Gore, W.; Harris, R. C.; Mitchell, C. H.; Randall, W. H.; Rust, C. H.; Salmond, J. J.; Storrie, W.; Wynne-Roberts, R. O.
Trenton...............Hicks, A. T.
Walkerville, Ont.....Brown, C. D.
Winnipeg, Man..... Blair, McC. P.; Ruttan, H. N.; Scott, W. M.; Stainton, H.

CORPORATE

Brantford........Brantford Water Commissioners
Galt.......................Galt Water Commission
London................Public Utilities Commission
Peterborough ..Peterborough Utilities Commission
Sault Ste. Marie.........City Water & Light Co.
St. Thomas.......St. Thomas Water Commissioners
Waterloo....Waterloo Water & Light Commission
Winnipeg...........Greater Winnipeg Water Dist.

ASSOCIATE

Toronto....Canadian Engineer, The

FOREIGN: Active 38; Corporate 1; Associate 2; Honorary 1; Total 42

ACTIVE

ARGENTINA:

Bahia Blanca........Anthony, C.
Buenos Aires...... Lasso, A. F.; Raffo, B. M.

AUSTRALIA:

Brisbane....... Hargreaves, J.; Henderson, J. B.; Peart, J.

AUSTRALIA:
- MELBOURNE.. { Neylon, C.M. B. L. / Ritchie, E. G.
- MILLBROOK.........Bradley, E. J.
- NEWCASTLE.........Ewing, James
- NORTH SYDNEY.......Smith, C. W.
- PERTH...........Trethowan, H. C.
- PORT AUGUSTA,..Saunders, F.W.T.

BRAZIL:
- SAN PAULO......... Pedroso, A. M.

CENTRAL AMERICA:
- SAN SALVADOR............Klein, F.

CANAL ZONE:
- BALBOA HEIGHTS....Bunker, G. C.

CHILE:
- SANTIAGO.................Neut, G.

CUBA:
- HAVANA....... { Cosculluela, J. A. / Montoulieu, H. J.
- MATANZAS............Heydrich, A.
- SALAMANCA..........Hobby, A. S.

ENGLAND:
- BEXHILL-ON-SEA.. ....King, C. P.
- TUNBRIDGE......... .Jarvis, A. C.

FRANCE:
- PARIS................Cavallier, C.

HAWAII:
- HONOLULU.........Murray, H. E.

INDIA:
- NAMTU (Burma)...Jenks, H. N.
- CALCUTTA........ { Cameron, A. P. / Lawton, R. W.

IRELAND:
- WEXFORD ....Wickham, J. T.

JAPAN:
- TOKYO .... { Inoue, S. / Nishioeda, S.

MEXICO:
- GUADALAJARA.....Blake, C. H. M.

PHILLIPINE ISLANDS:
- MANILA...............Gideon, A.

RUSSIA:
- PETROGRAD... { Kapoustine, T. / Kontkovski, E. B.

SCOTLAND:
- ABERDEEN.............Mitchell, G.
- DALCROSS...... .McIntosh, W., Jr.

STRAITS SETTLEMENTS:
- SINGAPORE...........Tomlinson, S.

CORPORATE

AUSTRALIA:
- SYDNEY..Metropolitan Bd. of Water Sup. & Sewage

ASSOCIATE

SCOTLAND:
- CRAIGWARD........McQuistan, A. N.
- GLASGOW.........Stewarts & Lloyds

HONORARY

JAPAN:
- TOKYO......... ......Nakajima, Y.

SUMMARY BY STATES

	Active	Corporate	Associate	Honorary	Total
Alabama	8	1	2	..	11
Arizona	4	..	..	..	4
Arkansas	..	1	..	..	1
California	28	5	..	1	34
Colorado	8	..	1	..	9
Connecticut	21	1	3	1	26
Delaware	6	..	..	..	6
District of Columbia	8	..	..	..	8
Florida	8	..	..	..	8
Georgia	13	..	..	..	13
Idaho	2	..	..	..	2
Illinois	103	3	15	..	121
Indiana	19	3	2	..	24
Iowa	42	1	1	..	44
Kansas	11	1	..	..	12
Kentucky	17	4	1	..	22
Louisiana	8	2	..	..	10
Maine	18	..	..	..	18
Maryland	16	..	..	..	16
Massachusetts	37	..	5	..	42
Michigan	27	4	1	..	32
Minnesota	34	2	1	1	38
Mississippi	6	..	..	..	6
Missouri	29	3	1	1	34
Montana	4	1	..	..	5
Nebraska	6	1	..	..	7
Nevada	2	1	..	..	3
New Hampshire	..	1	..	..	1
New Jersey	65	6	6	.	77
New Mexico	..	2	..	..	2
New York	181	14	43	..	238
North Carolina	16	..	..	..	16
North Dakota	5	..	..	1	6
Ohio	44	3	9	..	56
Oklahoma	2	..	..	..	2
Oregon	3	1	..	..	4
Pennsylvania	107	9	24	..	140
Rhode Island	2	..	1	..	3
South Carolina	7	1	..	..	8
South Dakota	2	..	..	..	2
Tennessee	13	2	2	..	17
Texas	6	2	..	1	9
Utah	1	..	..	..	1
Vermont	2	..	..	..	2
Virginia	16	2	2	..	20
Washington	6	2	..	..	8
West Virginia	7	..	..	..	7
Wisconsin	24	1	2	..	27
Wyoming	2	..	..	..	2
Canada	53	8	1	..	62
Foreign	38	1	2	1	42
	1087	89	125	7	1308

Title Page
+ Content

VOL. 5 NO. 4 DECEMBER, 1918

PROCEEDINGS 38TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED IN MARCH, JUNE, SEPTEMBER AND DECEMBER BY THE

AMERICAN WATER WORKS ASSOCIATION

AT 2419–21 GREENMOUNT AVE., BALTIMORE, MD.

SECRETARY'S OFFICE, 47 STATE ST., TROY, N. Y.

Subscription price, $5.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917,
authorized August 6, 1918

// JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 5 DECEMBER, 1918 No. 4

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JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

VOL. 5 DECEMBER, 1918 No. 4

COMMENTS

WHAT INTERESTS WATER WORKS MEN MOST

At the St. Louis convention the proposal to make the JOURNAL a more useful publication met with warm approval. To do this makes it necessary for the Publication Committee to try to solve the old and troublesome question of what interests water works men most. The technical journals have their editorial representatives traveling about all the time, meeting the men who are in charge of all kinds of work and thus learning what they wish to know as well as what they are doing. They succeed as they keep in touch with their field in this way, and they fail as they edit their journals from the office chair alone. Each member of the Publication Committee is busily engaged in solving his own problems of administration and construction and investigation; none has time to travel about on editorial work. Consequently, at the outset of the new duties put upon the Publication Committee, the members of the Association should let the Committee know what, in their opinion, is the field in which water works men take most interest.

It is a most troublesome and bewildering experience to spend long study and carry on protracted correspondence in order to write a comprehensive summary of the present views held on a subject of really great importance, only to find that this report is regarded as a dead issue. Such an experience is not likely to encourage those who have had it to renewed activity of this character. For example,

take the report of the Committee on Depreciation. After a great amount of correspondence and study, the committee prepared a report which was submitted at the Richmond convention, along with a minority report by one of its members. The subject was so important and the report was known to be the result of so much effort, that rather than take hasty action on it, the report was ordered printed and distributed to the members and placed on the program of the next convention for final discussion and action. But at St. Louis the matter had been so forgotten that no action was taken in accordance with the vote of the Association the year before, and the fact that the committee had been discharged at its own request at Richmond was overlooked. As a result one of the most important reports made to the Association still remains without action and existing only in pamphlet form.

This report was a subject of great interest at Richmond; it was a dead letter at St. Louis. What then should be the guide of the Publication Committee in determining matters of interest to the members of our Association? Letters from acquaintances tell what interests them; I know what interests me. But one man's circle is a small one; the Committee wishes to know what interests water works men all over the country, so it can make the JOURNAL a very live help to them, whether they are managing a small plant or managing the water supply of a great city. The Committee cannot send a letter of inquiry to every water works man in the country about this matter. But every member of the Association who feels that a live journal will be useful to him should let the Publication Committee know how it should be changed to make it more serviceable to him personally.

A. W. CUDDEBACK.

CONSERVATION OF WATER SUPPLY BY WATER WASTE PREVENTION INSPECTION

The participation of the United States in the World War has more forcibly than ever before impressed water works officials with the necessity of conservation of water supply. The federal authorities responsible for the prosecution of the war are daily urging the use of what was formerly wasted, to reduce the demand for labor and materials. The water consumption of communities is being studied to determine whether undue waste of water exists, and if so, a de-

mand is made to curtail such waste. Coal is to be allotted on the basis of the actual water needs of cities with waste stopped, as far as practicable. Whether our federal representatives have or have not taken action on the fuel allotment of a given community, all should be interested in water supply conservation for one of the following reasons:

a. To avoid shortage in supply, due to abnormal growth in consumption, on account of war activities.

b. To conserve fuel and labor, where pumping of the water is necessary.

c. To relieve the overload on delivery mains, filters and other essential parts of a water supply system which cannot be duplicated under war conditions.

Emphasis has in the past been, and is now being, laid on the use of meters to reduce the demands for water, by checking waste. Only slight effort has been made to direct attention to the excellent and almost immediate results in water waste prevention that can be obtained from house to house inspection. Under present labor and material conditions it is both difficult and expensive to obtain and set meters. By the expenditure of a small fraction of the labor necessary to install the meter, the premises can be examined and plumbing repaired, to prevent waste from leaks. It is estimated that in generally unmetered communities, water can be saved by a yearly inspection of the premises at a cost of approximately $5 per million gallons. No additional water can be obtained at a price that even approaches this figure.

The water works superintendent should not neglect the possibilities of conserving his supply and reducing his operating expenses, through the periodical examination of plumbing within the houses. New York and Buffalo have recently found that many million gallons daily, and tens of thousands of dollars annually, are saved by the inspection of premises to detect and stop leaks. Men for this work may be readily trained and immediately secure results. By their use the careless, wasteful consumer is made to save the water that his careful and conscientious neighbor pays for.

It is not intended to create the impression that house to house inspection should be considered as a satisfactory permanent substitute for general metering. The measurement of and payment for water furnished can only be equitably based on records of meters attached to each premise. There is no water waste preventive

equal in efficiency to a meter, but there may be many reasons why meters cannot be installed. The examination of water fixtures by inspectors is now urged as a valuable aid in reducing water consumption during the period which must elapse before meters can generally be installed under the war time conditions existing in this country.

W. W. Brush.

WRITING FOR PUBLICATION

Every experienced superintendent is confident he can edit his favorite trade paper better than it is now edited, at least in some particulars. Yet the fact is that the publishers of trade papers, whose success depends upon their ability to produce publications which large numbers of specialists like enough to buy, use only a very small part of the information in the articles presented by these specialists before technical societies. Furthermore, there are only a very few technical societies which publish journals that even pay expenses, unless a wholly unreasonable proportion of the annual dues are assumed to be paid solely for the journals. The societies, such as the Society of Chemical Industry, which publish profitable journals, conduct this part of their activities precisely like the publishers of trade journals. Therefore it is reasonable to believe that the methods of editing a successful trade journal are worth explaining at this time to the members of the American Water Works Association, for our printers have been compelled to increase their charges for publishing our Journal about one-third, and it is necessary to adopt more economic methods in preparing papers for presentation and publication, in order to keep well within the budget for printing expenses. Furthermore the War Industries Board has ordered the amount of paper used in the Journal reduced about 20 per cent.

There are two entirely distinct classes of papers published by technical societies. The first class is essentially news; it describes work planned, or under construction, or done. The second class is scientific; it describes investigations, analyzes the reasons for success or failure of methods of design or construction, reviews the state of some particular art or practice, or discusses those principles of economics which underlie sound business administration.

News articles must be brief. Fifteen years ago, it was the practice, even in trade papers, to embalm the kernel of news in a husk of

everyday knowledge, so that we were forced to waste our time needlessly in acquiring new information. James H. McGraw saw the mistake of this custom, and was the first leader among American publishers of trade papers, to insist that the news should be printed without the platitudes. Every reader of a trade paper owes him thanks for saving their time by starting this reform. We can waste money and yet earn more, but we cannot get back the time we waste, and we are wasting our most precious asset in padding news articles, in addition to wasting the time of the readers of them who have to read the superfluous paragraphs.

There is another feature of this subject that every man holding a technical or administrative place should keep in mind. Much of the best news, particularly in the water-works field, can be written on two or three sheets of paper. This is easily done; it results in something others in the same field desire; why not do it now and let the members of our Association share this interesting information, instead of putting it off until there is an opportunity to wrap the news in the old-fashioned husks? Why not openly confess that while examining the journals of many technical societies we long for some sort of literary gas mask?

The second class of articles, that dealing with scientific subjects, is a large one and has so many aspects that only the most general suggestions regarding it can be made here. Obviously the best method of presenting the results of special research is different from the best method of reviewing the state of an art, yet there are certain principles that govern the editorial staffs of our best trade papers which should govern everybody who writes on a technical subject. These are:

1. Have a clear knowledge of the viewpoint of the class you wish to read your article. You are not trying to get information out of your head; you are trying to get it into their heads; hence use the best way into them.

2. Don't give an unnecessary fact or make an unnecessary explanation of minor details. Assume that the reader possesses as much knowledge as you have, except of the new thing, and tell him about that only.

3. Tell the story in the clearest way by words, drawings or pictures, but tell it only once. Don't give both tables and curves; one is enough for practically every reader and let the hundredth man write to you for the omitted details that all the others do not

wish. Think of the time and printing charges this saves. Don't describe in words what is perfectly clear in illustrations; don't repeat in words what is given in detail in tables.

4. Don't give unnecessary tables; assume that the reader will grant that you know how to add and subtract, and is interested only in totals, as a rule. Prepare your tables so that they will occupy the smallest amount of printed space and still be clear. Look at tables in the publication for which you are writing, see how many figures can be put on a line in the column or the page, and arrange your tables accordingly. Otherwise somebody must rearrange them for you, and probably make mistakes in doing so.

5. Send drawings that can be photoengraved and save the Association the expense of making drawings for the purpose. Never use colors on drawings for photoengraving. Remember that if a drawing must be reduced to one-third, say, of its size to be printed on the page, each line and letter on the drawing must be three times the size it is to be on the engraving. Use only two sizes of lettering on such a drawing, one for the text and one for the very few titles sometimes necessary. Don't give a line or a word not absolutely necessary. If the drawing has a single detail that is much finer than all the rest, make an outline of this detail on the main drawing and then, on a larger scale, give the detail; this will enable the general drawing to be photo-reduced to the size it should have in the engraving and will also give the detail in legible form, a great help to the reader and a saving of expense to the Association.

6. Remember the many times you have wondered why the Journal was padded with so much useless stuff; don't pad. Remember how many times you wished for news about some improvements or some piece of work; send the Journal your own news or tell the Publication Committee what you wish. Remember that nine-tenths of good technical practice is the result of sound judgment and only one-tenth depends upon demonstrable facts; help others with the practical knowledge upon which good judgment rests, just as others are helping you.

John M. Goodell.

BURNING SMALL SIZES OF ANTHRACITE

Many years ago the late Eckley B. Coxe, the noted mining engineer and coal operator, saw the approach of much higher costs of pro-

duction in the anthracite fields. He also saw
of coal through failure to develop practical
the small sizes which were then rarely used.
worked over this problem and finally developed
and grate for burning these small sizes, but as
ripe for its use, it was forgotten by most po
Recently the high price of larger sizes and th
deliveries of them have made the use of small
and this old invention has again come in
Philadelphia Water Bureau has been one of
new practice, which is of real significance as
economy. From the best data available the
sylvania of these small sizes of anthracite, co
No. 3 and No. 4 buckwheat, has doubled in th
other words, about 2,000,000 tons annually of
went to waste is now being used in power plan

The Philadelphia Water Bureau has installed
in the past four years under boilers aggregati
8400 horsepower. A combined efficiency of 70
cent of boiler rating has been obtained in all t
wheat coal having a heat value of 11,000 B.t
proximately 23 per cent of ash. Operating res
test conditions in a way that demonstrates the
stroker and the fact that it can be consid
experimental stage.

Conditions in the fuel market dictated the
stoker which could burn anthracite screening
No. 3 buckwheat averaged approximately $
rather more than $1.00 a ton less than for bi
value of 13,000 B.t.u. and 13 per cent of a
conditions created by the war have more tha
of this stoker, entirely apart from the artificia
the present abnormal situation.

Conditions after the war will apparently o
for stokers of this type in the contemplated
in the mining regions, as well as in the use of
must be largely developed in the future.
Island lignite has already been successfully
mental way. The near future will certain
permanent changes in all our boiler room p

While freight charges will doubtless limit the areas beyond which low grade fuel cannot be economically transported, the chain grate stoker of the Coxe type apparently opens one practical line of investigation for many water works superintendents.

CARLETON E. DAVIS.

COAL

There seems to be a considerable misunderstanding of what must be done by the managers of water works and other public utilities to obtain coal. All public utilities have been given a definite classification which gives them preference over many other consumers of fuel. This is a classification which gives a preference under war conditions; it does not mean a preference which will restore the conditions existing in times of peace. Nobody has the slightest justification for expecting that a preferential classification here will remove all troubles any more than our soldiers in Flanders and France had any reason for expecting sleeping cars and limousines to transport them through the enemy's lines. The coal operators are crowded to the utmost and the railways in many sections are congested. Under such conditions, inconvenience is bound to arise and the manager of the public utility who gets along best is he who sees what this inconvenience will be and provides against it.

There have been innumerable complaints from managers of utilities that coal was not delivered when it was desired but came at long intervals in large quantities which could not be stored. That condition is a war time burden which the manager must provide against. In congested districts coal can often be delivered only in large consignments, without interfering with essential war time shipments. The wise manager will provide storage somewhere for this coal; if he does not, a variety of harassing troubles are likely to visit him, and he will receive little sympathy from those who know how strained are the railroad facilities to meet the urgent demands upon them. It is impossible in many places to deliver a car or so of coal at regular intervals, without interfering with so many other necessary freight movements that national economy demands placing upon those heretofore served in this way the provision of increased storage facilities. This is their share of the war burden, so far as the coal situation is concerned.

There is a mistaken idea that the place to untangle complications over coal deliveries is Washington. It is a good plan to keep away from Washington in these days. The Fuel Administration is decentralizing its work so far as possible. A manager short of coal and unable to get help from the local fuel administration should deal with his State fuel administrator. The latter is an extremely busy man, working with a hastily organized force. There are two things which should not be demanded of him. One of these is how to furnish coal on a day's notice in a district where transportation is congested and coal is short. The other is to have such a complete filing system and such a well-organized clerical force that the coal business of a state can be looked after with the detail maintained in a local dealer's office.

In order to have enough coal on hand the manager of a utility must give the State Fuel Administrator ample notice of his needs, he should give full data in each letter so that previous correspondence must not be looked up in the office of the administrator, he should show how much he burned last year and the reason for asking an additional amount this season, and he should use every endeavor to take coal when he can get it and not when he wants it. He must put up with many inconveniences but they are nothing to the daily troubles of the fuel administrators who are trying to help him.

JOHN M. GOODELL.

DE-HYDRATED CONTRACTS[1]

By Albert P. Greensfelder

Contracts are not engineering products but merely recipes for moral behavior. Water works were probably built by the ancients without such entangling alliances. Even today water free from impurities is possible without the introduction of paper documents. Why then are there such impedimenta as contracts?

Civilized anatomies demand water of quality and civilizing industries require water in quantity. Contracts, per se, affect neither of these, any more than do meters and pumping records. There is probably nobody here who, when stating his experience before his prospective employer or examining board, was ever asked if he could write a contract. If such a test were a requirement of water works officials the speaker would greatly fear for the constant supply at our faucets. Thus all will probably agree that contracts are de-hydrated.

If any one present, irrespective of practical construction experience, were asked to adjourn to an adjacent room and, without books or other references, prepare an equitable form of contract in five or even fifty hours, it is probable the results would be neither equitable, legal, nor binding. The task is difficult because it is based on precedent and comparative experience, but it is not impossible, as has been amply proved in other fields of endeavor.

The true purpose of a contract is to express so clearly the intent of those making it that a meeting of the minds of the two parties thereto is absolute. In these days of conservation of man power and wealth the necessity for proper contract forms is more essential than ever before. We must not, dare not, waste effort in these strenuous times. The American Society of Engineering Contractors therefore deems it both a prerogative and a duty to call upon its allies to function properly and promptly in this regard.

[1] Abstract of an address by the president of the American Society of Engineering Contractors before the St. Louis Convention May 15. At the close of the address the Association voted in favor of the appointment of a committee on a standard form of contract and bond.

This subject is no new field of endeavor for an organization such as the American Water Works Association, for a number of technical organizations have prepared similar documents in recent years. The American Institute of Architects in conjunction with the National Association of Builders' Exchanges and others has compiled splendid forms which have now reached their third edition and are universally used by members of their profession on building work. The American Railway Engineering Association, through a standard committee, has prepared an excellent ready-to-use form for its members. The latter society has achieved an enviable position in this country, for many courts recognize its annual "Manual" and permit its introduction as evidence in establishing maintenance-of-way standards.

The publications of these two societies are standards in their respective branches, not mythologies but standards in the sense that they are the products of their ablest members working together for the best results; yet subject to occasional revision and betterment as experience in their use shows this to be desirable.

Is the public to be blamed for becoming impatient at excessive costs, running unquestionably into hundreds of thousands of dollars annually, due to questionable terminology? Are contractors wholly to blame for being suspicious of motives for the insertion of special clauses and one-sided paragraphs? Are not bonding companies raising rates on account of unnecessary penalty clauses and long-time guarantees? The banks charge more interest on retained percentages than city treasurers get; and payments for special materials delivered long before incorporation in the work will make liens infrequent and prevent delays. Flexible methods of payment have been known to dispel disagreeable receiverships and arbitration clauses are merely expressions of human justice to eliminate interminable court proceedings.

The speaker is not here to propose any favorite terms, to nurse pet hobbies for inclusion in any special contract forms or to propound any exclusive theorems for elucidation. He desires merely to have water works officials feel that contractors are just as keenly alive to their obligations and responsibilities as he knows the officials are to theirs. Contractors have not been beyond reproach, and occasionally even worse, but they realize fully that through the influence of their members collected into a society their tendencies are for improvement and they have a sincere desire to coöperate.

The American Society of Engineering Contractors upholds strict measures which make for quality of construction, it invites the proper placing of responsibility, and it urges encouragement and recognition of good construction service. It admits that contractors are human beings with human ambitions, but it believes reliability is more worthy than cupidity. Contractors remain in their calling because they enjoy its rewards, labors and sorrows better than those of other fields of endeavor and because they hope their work is a genuine service to mankind.

LEAD PIPE COUPLINGS[1]

By J. A. Jensen

The object of this paper is to discuss the joints commonly used in service pipe connections and the development that has taken place from time to time under the guiding light of experience, for the purpose of improvement and prolonging the life of the service and its various appurtenances.

A service pipe, as discussed here, consists of a corporation cock at the water main, a run of lead pipe to the curb or walk, where a stop cock is placed and covered with a box extending to the surface of the ground, and galvanized iron pipe continued to the premises. Lead pipe is selected because of its durability and necessary physical properties for conditions generally met with in most localities. Galvanized iron pipe is suitable for the remaining portion of the run from the stop cock to the building. The cocks are made of bronze or non-corrodible metal for the purpose of resisting deterioration and, as a consequence, to permit ease of operation.

The principal object in the selection of materials and fittings is to make up a suitable and durable structure that will insure the owner minimum repairs and troubles from leakage. Aside from corrosion of materials, consideration should be given to the various kinds of joints used for connecting the several parts of the service pipe.

The use of lead pipe probably originated the so-called "wiped joint" or soldered connection to the cocks. There were originally in use the fixed soldering nipples. These later gave way, for obvious reasons, to the separate nipples and tail pieces, with their necessary couplings, all of which are now commonly used. For the iron pipe, the common threaded fittings are convenient and apparently suitable for all purposes.

Any improvement in the various parts of a service pipe is naturally based upon the troubles arising from leakage. The leak is the alarm that calls attention to the condition of the service. These leaks require considerable attention by water departments to locate

[1] Read before the St. Louis Convention, May 16, 1918.

the trouble, to serve notice upon the owner and to see that prompt repairs are made.

For some time the City of Minneapolis has given consideration to the matter of service leaks that occur between the water main and the meter. During 1917, there were 642 cases of such trouble which were repaired by licensed plumbers under the supervision of the water department. These leaks not only give trouble and expense to the owner, but also cause a considerable loss of water to the municipality. This loss has been variously estimated at from 15,000,000 to 20,000,000 gallons per year. These services are owned by the consumers but the city supervises their maintenance to prevent loss of water.

The number of leaks referred to is an increase of 19 per cent over the previous year. With an increasing number of services approaching the age of trouble and replacement, further increase in the number of leaks must be expected.

There are no practicable means for the reduction of leaks occurring in existing services, but in order to prolong the life and lessen troubles on services that will be installed in the future, a study was made to discover the precise nature of existing troubles so that the proper remedy could be applied.

At present the service connections are made up of a corporation cock at the main, tail piece with wiped joint to lead pipe leading to the stop cock at the curb where it is again wiped to a soldering nipple. From this point to the meter, galvanized iron pipe is used. All of the wiped joints are made by licensed plumbers who install all services under city inspection.

A classification of service leaks was made and some interesting data have been obtained which indicate clearly the various kinds of trouble encountered. The classification was as follows:

1.	Defective curb cock	6	1.0 per cent.
2.	Iron pipe, corroded	302	47.0 per cent.
3.	Lead pipe, corroded or burst	96	15.0 per cent.
4.	Wiped lead joints	238	37.0 per cent.
	Total	642	100.0 per cent.

In considering only the serious leaks in this table, those that occur in iron pipe might be set aside, since such pipes are accessible for repairs without disturbing walks or pavements to any serious

extent. The portion of the service that should be most secure and durable is the lead pipe and its connections which are located under the roadway and in the majority of cases under pavements.

The street leaks may then be separated and reclassified as follows:

1.	Defective curb cock	6	2.0 per cent.
2.	Lead pipe, corroded or burst	96	28.0 per cent.
3.	Wiped lead joints	238	70.0 per cent.
	Total	340	100.0 per cent.

An examination of these street leaks shows the following facts to be apparent:

1. The curb cocks enumerated were found to be defective. They were all old-style cocks which have since been replaced by an improved type by the use of which a minimum amount of trouble will be experienced in the future.

2. The table shows 28 per cent of street leaks to be in the lead pipe itself. About one-sixth of these were due to bursts by swelling of the pipe from repeated water hammer caused by defective faucets. Inspection of these showed all such pipe to be of lighter weight than that used at present. One-fourth of the lead pipe troubles were found under car tracks and the pitting and corrosion clearly indicate electrolysis. The remaining leaks were due to other causes, though many of them also appear to be from the effects of electrolytic action. Since heavy lead pipe is now used and means are employed to eliminate electrolysis, these troubles are already reduced to a minimum, so far as the future is concerned, and justification found for the continued use of lead pipe.

3. The wiped joint leaks make up 70 per cent of the street leaks and troubles. These leaks are due chiefly to inferior workmanship. In most cases there has been failure to secure proper bonding in the joint. A number were "lop-sided;" others barely covered the end of the tail piece and in several cases the solder had run inside and partially closed the water opening. One joint had an opening left no larger than a pencil and after a remarkable record of patience covering a period of 24 years, the owner had the service dug up and the trouble was discovered and corrected. Many of these joints stood up for many years before giving way.

Several years ago lead pipe was used extensively in all plumbing work, but at the present day it has been replaced almost entirely

by improved plumbing appliances and fittings made of other materials than lead, so that the art of wiping lead joints has passed into the hands of pipe fitters rather than the plumbers of former days. In many shops the wiped joints on service pipes form the only work of this nature that is encountered, and it must be undertaken as a special task. The work is attempted by unqualified and incompetent persons not familiar with nor skilled in the art. The result is that present-day wiped joints, under these conditions, do not measure up to the standard of former times, and more trouble may be expected in the future than in the past if such joints continue to be installed.

It appears from a consideration of this matter that these facts have been recognized in various cities. Efforts to secure protection against inferior joints have resulted in the development of a connection that is superior to the wiped joint.

This joint is a mechanical connection in the form of a coupling in which the lead pipe is shaped to form its own gasket. The lead flange should undergo slight reaming to make true parallel surfaces for close contact. The couplings should have plane faces, at least in part, to insure a good joint and must not be permitted to cut the lead flange. The coupling should have a sleeve to cover a short portion of the lead pipe close up to the flange to prevent any movement or deformation of the lead at the joint. The shaping of the lead flange may be conical or at right angles to the axis of the pipe.

There are several types of this joint on the market, all having desirable features of design, but the principle is similar in all cases. The coupling is made a part of the corporation or curb cock and is of composition metal. The joint develops the full strength of the lead pipe and is equally as strong as the best wiped joint and superior to it in results because it can eliminate defective workmanship.

Tests made in the presence of waterworks men have demonstrated conclusively that rupturing stresses applied as internal pressures and tension on lead pipe secured at both ends by flanged curb cocks, have failed to break the joint or injure the coupling. In all cases the lead pipe burst or parted.

The initial cost of the material for this joint is slightly greater than for the wiped joint, but when the necessary labor is added, this cost is more than offset. The cost to the property owner ought at least to be practically the same. An intelligent man can make a

flange coupling joint with simple tools and a pair of wrenches in a very short time, and on the ground where required. The need of a plumber with a blow-pot and other appliances is eliminated.

The comparative cost of the wiped joints and flange couplings in an ordinary service, at recent prices and labor costs, is as follows:

⅝-inch wiped joint corporation cock	$1.05
¾ inch wiped joint curb cock	2.40
2 pounds solder, two wiped joints	.80
Plumber's time, 1 hour	.90
Total cost wiped joints	$5.15
⅝-inch flange coupling corporation cock	$1.30
¾-inch flange coupling curb cock	3.15
Time making joints, 1 hour	.40
Total cost flange joints	4.85

This shows a balance of $0.30 on each service in favor of the flanged joints which can be considered as a margin for fluctuation in cost of materials and labor.

In considering the data given, the use of lead flange joints promises longer life to service connections as a whole, and a consequent reduction of leakage troubles and expense to both the city and property owner.

The street service department of Minneapolis has used lead flange couplings of different types for repair work for several years and they have been satisfactory and successful in every way. They have not only proved more convenient than the wiped joint for the department, but their use has also resulted in the saving of time and money in every case.

OFFICE RECORDS OF THE ST. LOUIS WATER DIVISION, DISTRIBUTION SECTION[1]

By Thomas E. Flaherty

This paper will give a brief description of the organization for the planning, direction, and execution of the work of the distribution section of the St. Louis water department, and a somewhat fuller description of the recording of the work by clerks and draftsmen and of the methods of making corrections and additions and of supplying missing information.

The personnel of the force comprises an engineer-in-charge, assistant engineers, superintendents of construction, labor, stables and vehicles, meters, inspection; a chief draftsman, chief clerk, and the draftsmen, clerks, stenographers and helpers working under these men.

For distribution purposes, the city is divided into six districts, each having a station building, with a station foreman in charge. The most central of these stations is used as the construction superintendent's headquarters, and is known as the "main distribution office," from which all orders emanate, and to which all reports are sent. Another station, known as the "pipe yards," is used as a supply depot and meter testing station. Each district is divided into sections, in charge of section men reporting to the station foreman.

All material is tested before being used; the pipe, valves, hydrants, special castings, and fittings are tested at the place of manufacture, and all other material at the City Testing Laboratory. The test records are kept at the main office in the City Hall. Pipe for contract work is delivered by railroad to depots in different parts of the city, convenient to the work. All other material is stored at the pipe yards and delivered as needed. Records are kept at the pipe yards showing in detail the exact stock on hand at all times.

On receipt of petitions for water mains from proprtye holders on certain streets, or upon notice from the Street Division that certain

[1] Read before the St. Louis Convention, May 16, 1918.

streets (without water mains) are to be paved, or when new mains appear to be needed for distribution purposes, record cards are made out, showing the names and extent of the streets. An inspector then ascertains the number and story-heights of all houses on the street, and the kind of pavement, if paved. An engineer then determines the size and length of pipe, number of fire hydrants, valves and special castings needed; estimates the cost of material and labor and total cost, and tabulates these items on the card. The engineer-in-charge will then place on the card a check mark in such a way as to show at a glance whether the work is recommended or not recommended. In a somewhat similar way various requests for additional fire or sprinkling hydrants, private connections, fire lines, etc., are received, considered, and either recommended or not recommended. These records are then filed for future reference.

All contract work recommended must be approved by the Board of Public Service and contracts awarded for the work. A record is kept, year by year, of all bids received, and the supply clerk keeps a card index of the current prices of all material used by the Water Division. On pipe lines, lowerings, etc., the engineers make plans and profiles of the work, stake out the line and enter their notes in the customary engineer's field book. The plan and profiles and a copy of the engineer's notes are then given to the contractor, or in case of work to be done by the Distribution Section, to the Superintendent of Construction, with instructions to lay the pipe, castings, etc. On small jobs simple instructions are issued to do the work, accompanied when necessary by sketches and memoranda giving all necessary data. On the larger jobs regular pipelaying inspectors are assigned. On the smaller jobs, the station foremen act as inspectors. Longer jobs (not contracts), pipe laying, and pipe lowering are done by pipe-laying foremen in charge of what are known as "floating gangs." These men work in all sections of the city, reporting to the Superintendent of Construction at the main office.

The pipe-laying inspectors keep a daily record of labor and material used, and obtain and record measured locations of all pipe, hydrants, valves and special castings, etc. This record is known as the "inspector's notes." On the smaller jobs and routine work the section men fill out a "daily report sheet," ruled in three columns, viz: "Name," "Time," "Work done and material used." The station foremen obtain and record the measured locations,

which, with the "daily report," are collected by the Superintendent of Construction and brought to the main distribution office. Here, under the direction of the Chief Clerk, a stenographer types these memoranda into sheets known as distribution notes, if the work is done for the city, and "private connection notes," if done for private parties.

At the end of each month the chief clerk forwards to the chief draftsman a "recapitulation sheet" of all "distribution notes" and "private connection notes" sent down from the main office. This list is checked against the chief draftsman's "posting record," and must agree with it, so that no notes can be lost in transit between offices. The engineer's notes, profiles, distribution notes, and private connection notes are now turned over to the chief draftsman, who numbers the notes serially, and enters them in a "posting book," and is then responsible for the correct platting and recording of the work done on all the drafting room records, and of indexing and filing these records, so that they will be instantly available when needed.

The regular drawings of hydrants, special castings, valves, tools, buildings, etc., are filed in a vertical steel plan file, and indexed in the usual way. Profiles and foreign drawings are rolled up and filed serially in numbered tubes in metal pigeon-hole cases, and card-indexed according to subject matter.

The draftsmen may then post the maps and other records in the following order:

First Posting.—This is done on the distribution map. This is a map of the entire city, on a scale of 1320 feet to the inch, on which high-pressure mains are shown in blue and low-pressure mains in red. The size of the pipe is accurately indicated by the thickness of the line; $\frac{1}{5}$ inch indicates 48-inch pipe, $\frac{1}{6}$ inch 36-inch pipe, $\frac{1}{8}$ inch 30-inch pipe, $\frac{1}{16}$ inch 20-inch pipe, $\frac{1}{20}$ inch 15-inch pipe, $\frac{1}{32}$ inch 12-inch pipe, $\frac{1}{40}$ inch 10-inch pipe, $\frac{1}{64}$ inch 8-inch pipe, a single thin line 6-inch pipe, and a single thin dotted line 3-inch or 4-inch pipe. No hydrants, valves, or special castings, except the separating valves between high and low pressure, are shown on this map. On all other records the size of the pipe and nature of the special castings, etc., are shown by the conventional signs or symbols. Thus three lines close together, two of them dotted, enclosing a central full line, indicate 48-inch pipe; two full lines enclosing a central dotted line, 36-inch pipe ;three full lines 30-inch pipe; one

full line and one dotted line, 20-inch pipe; two full lines, 15-inch pipe; two dashed lines, 12-inch pipe; single dashed line, 10-inch pipe; single dot and dash line, 8-inch pipe; single full line, 6-inch pipe; single dotted line, 3-inch or 4-inch pipe, the size being written on the line if necessary. Conventional signs are used for different types of valves, hydrants, and other accessories.

Second posting; section maps. These maps are on a scale of 200 feet to one inch, only nineteen being required for the entire city. About 125 city blocks appear on each section map. Cloth blue prints of these maps, mounted on map rollers, are kept at the various stations. These maps are invaluable, especially to the "night station foreman." The numbered separation valves are shown on these maps as well as all other valves, special castings, hydrants, etc. If a water main of any size should burst or a joyrider break off a hydrant and a flood threaten any locality, the foreman refers to the map of the scene of the accident and orders his gang to close the proper valves until repairs are made.

Third posting; loose-leaf plat book. These plats are on a scale of 100 feet to the inch, 278 of them being required for the entire city. About thirty city blocks are shown on each plat. On these plats a given city area occupies four times the space it occupies on the section map, and of course shows the pipe, hydrants, valves and other specials far more clearly and distinctly. These plats are consulted on all occasions where exact measured distances, pressures, grades, etc., are not required.

Fourth posting; street intersection cards. These are on a scale of 50 feet to the inch, over 6000 being required for the entire city. These cards, when completed, show on one-half of the card, the building and curb lines of all street intersections, and measured locations of all water mains, valves, hydrants, etc., within a radius of one-half the distance from the given street intersection to the next nearest street intersection along any street. On the other half of the card are listed references pertaining to the water main, i. e., the engineer's book and page, inspector's book and page, profile number, date of laying, pressure in pipes, and grade of street intersection at center lines of street. On the back of the card appears the name of the street, under which the card is classified and alphabetically filed, and on the front the name of the intersecting street. A serial number on the back indicates the place of the particular card in the "run" under which it is indexed. A trans-

parent envelope protects the card from soiling or blurring. These cards are in daily use, answering the thousand and one queries received from the public or from other city departments, where exact and specific information is required.

Fifth posting; separation cards. These are made for all intersections at the boundaries of high and low districts, and differ from the street intersection cards only in that the high pressure mains are shown in blue, and low pressure mains are shown in red, and the numbered separation valves are shown.

Sixth posting; sprinkling hydrants. A very complete and accurate list of sprinkling hydrants is kept. This list shows the number of "Sprinkling Districts," 42 in number, in the city, showing the number and location of the hydrants in each district, the total number which on January 1st, 1918 was 1894 hydrants.

All additions or removals during the previous year, and deductions to be made on account of oiled streets, and the amount due by sprinkling contractors for the use of the hydrants, are also accurately shown. In addition to this list, all hydrants are shown on a complete city map, scale 1320 feet to the inch, divided into sprinkling districts. Each hydrant is numbered, the number appearing on the map adjacent to the hydrant. Enlarged maps of each section on scales varying from 200 to 600 feet to the inch, are also kept so that the distances between hydrants can be scaled at any time.

Seventh posting; drinking fountains. All fountains are shown on a complete city map, scale 1320 feet to the inch. The character of the fountains is designated by conventional symbols for the various fountains installed by the city, by humane societies, saloons, etc., these fountains being for horses and in some instances for dogs or other small animals. Special symbols also indicate special ordinance fountains, metered fountains, or the new type known as "bubbling" fountains, from which citizens may drink when thirsty without danger of contamination. A numerical "District Book" of fountains and an alphabetical card index giving exact location, ownership, date of installation, memoranda relative to the maintenance and care and condition of the fountains, date of withdrawal, etc., are also kept.

Eighth posting; pressure records. Pressure gauges are maintained at six carefully selected points in the city, and the charts from them are collected and filed daily, thus keeping, as it were, a finger on the

"Water Pulse" of the city. In addition, numerous special gauge-readings have been taken at a number of well chosen points, at various grades, and platted on a city map, scale 2000 feet to the inch. By making allowance for differences in grades, we have computed reliable maximum, minimum, and average pressures, for practically the entire city. These pressures are recorded on the "Street Intersection Cards."

Ninth posting; pitometer records. A large number of pitometer readings have been taken at points selected with a view toward determining the direction and volume of the flow, by night or day, from the pump mains into the feed mains, and thence into the distribution mains to the consumer. These readings are recorded on a complete city map, scale 800 feet to the inch. On this map are drawn three sets of concentric circles, at one-mile intervals, covering the entire city. The center of one set of these circles is at the Baden High Pressure Pumping Station, one at the Bissell's Point Low Pressure Pumping Station, and one at the Compton Hill Reservoir.

These are the principal records to be posted; and as each record is posted, the draftsman marks on the inspector's or distribution note an abbreviation of the name of the record, as "D" for distribution map; "SP" for sprinkling map, etc. When the notations on the note show that all records have been posted, the chief draftsman OKs the note, and it is then pasted in a numbered "Gummed Stub" book. As the sheets are pasted in, they are paged serially, and index cards made up alphabetically, by street names.

In all municipalities, inherited records are more or less faulty and incomplete, owing in a large measure to continual changes in administration, poor systems in the past, the personal or human equation of the employes, or in some instances, as in that of our own city of St. Louis, to a fire at the City Hall some years ago, which destroyed a number of records. It is frequently found that measured locations are either altogether missing, doubtful, or evidently incorrect. To remedy this condition as far as possible, two methods were used with great success by the present administration, in the St. Louis Water Division:

1. Copies of the section maps previously referred to were laid out on a table at the main office of the Distribution System. The section foremen were then called in, one after another, and, with the chief draftsman, went over the maps carefully and minutely.

Where the section man recognized an error, or was in doubt as to any point, notes were made of the error or doubtful condition, and the corrections made when correct information was obtained, by inspectors delegated to this work. A very large number of important corrections were made in this manner.

2. In the drafting room a set of cards known as "Information Cards" (known among the draftsmen and engineers as "I. C." cards), are kept, and on them are entered requests for information on any doubtful point, for corrected locations, or for missing locations which develop in the course of the day's work. On each card is marked the number of the section, from which the information desired is to be obtained; and on the back of the card is marked the name of the street under which the card is classified. On the face of the card is marked the intersecting street, very much as in the case of the street intersection card. The cards are then grouped by sections, the streets being alphabetically arranged in their group. It is then a comparatively easy matter to send out inspectors to obtain the necessary information or obtain it direct from the section man in charge of the section.

By use of these two systems the faulty or missing information cases have been reduced to a minimum, and the value of the record system has been rendered nearly 100 per cent, in the present distribution system.

REINFORCED CONCRETE PRESSURE PIPE[1]

By Coleman Meriwether

Although concrete was used as along ago as 2300 years to build an aqueduct for the city of Carthage and later for the construction of aqueducts for Rome, it is only recently that pre-cast reinforced concrete pipe has been developed to meet the principal requirements of pressure lines. Experienced gained lately shows that concrete properly made and sufficiently reinforced will resist safely internal and external stresses up to 100 pounds per square inch. Correct methods of manufacture will produce pipe with a low coefficient of friction, experience having shown that a greater discharge was obtained from concrete lines than was anticipated. Leakage through the walls of pre-cast pipe has been almost nil and leakage through the joints has been less than is usually allowable for water mains.

As the construction of pipe lines is usually carried on at temperatures higher than that of the water which will flow through the conduits, it necessarily follows that contraction will occur. This will produce cracks at the joints through which considerable leakage will occur if provision has not been made to care for the contraction.

It may be assumed that the maximum temperature at the time of construction will be near 100° F. and that during the winter in some parts of North America the temperature will drop as low as 50° or more below zero. Pipe lines should be covered with the earth backfill before work is suspended for the winter and all openings in the pipe line should be tightly closed to prevent circulation of air in the conduit. With such precautions the temperature of the pipe line is not likely to drop below 40° F. Flowing water will have a temperature very little under 32° F. The above assumptions will give an idea of the range of temperatures and the consequent contraction and expansion in water conduits.

[1] Read before the Illinois Section, April 16, 1918.

One of the joints now used, figure 1, is constructed with a crimped copper band which is continuous throughout the circumference of the joint. As the pipe contracts the crimp opens and as the pipe expands the crimp closes. This joint is used in pipes 36 to 108 inches in diameter and is a true expansion joint, having been found successful in different parts of North America. To reduce the number of joints it is well to make the pipes as long as is practicable and trench conditions such as bracing, etc., may be limiting factors. The practice so far has been to make pre-cast units of a maximum laying length of 8 feet. It has also been determined in practice that it is necessary to equip each pre-cast unit with the copper expansion joint.

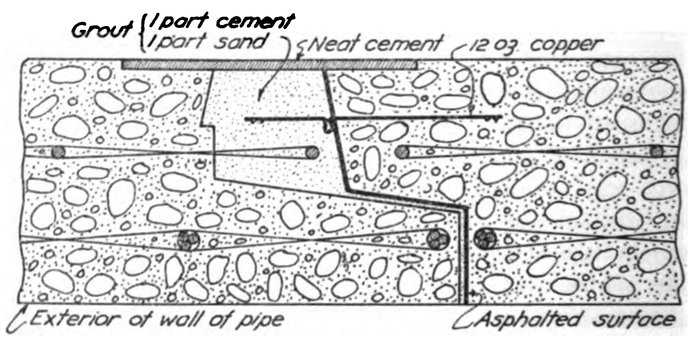

FIG. 1. EXPANSION JOINT.

The installation of a plant for manufacturing 66-inch reinforced concrete pressure pipe for 10 miles of the Greater Winnipeg water conduit in Manitoba, Canada, and some of the details of manufacture are described below. The layout of such a plant is a matter of no small importance, for incessant care must be used in all the details from the installation of the plant and its equipment until the last pipe is laid and the line tested.

Pipe are cast on end and the molds of sheet steel and cast iron must be erected on substantial foundations of reinforced concrete, the surface of the foundations being truly level and finished smoothly so that when the cast iron base mold is set and the sheet steel casings are erected the casings will be truly vertical.

The process of assembling consists, first, of cleaning, oiling and setting the cast iron bases on the concrete foundations. Second, the inner sheet steel casings are set on the bases and on top of them

is placed a steel filling platform used to center and hold truly circular the inner casings as well as to receive concrete from the conveying buckets. Third, the inner cage of reinforcement is placed, with its bottom strand set in an annular slot in the cast iron base; the slot is then filled with dry sand which forms a core and prevents concrete flowing into the space and thereby binding the base to the pipe. Fourth, the outer cage of reinforcement is set and the outer steel casing placed and clamped. The mold is then ready to receive concrete.

A batch of neat cement grout is dumped on the filling platform and flows into the mold, splashing over the two rings of reinforcement in its descent to the bottom of the mold. There a portion of the grout remains until the first batch of concrete is deposited, when this surplus grout rises with and is incorporated into the concrete and thereby replaces any grout which may have been abstracted from the concrete by the reinforcement. This is necessary to secure a pipe dense throughout its mass. The first batch of concrete is dumped on the filling platform almost as soon as the last of the grout flows into the mold, and each mold is filled very quickly, not enough time elapsing to cause any line of separation between batches. The filling is continuous from start to finish. All parts of the molds are cleaned and oiled between each filling.

In the manufacture of most pre-cast concrete pressure pipe it is necessary to use 1 volume of portland cement, $1\frac{1}{2}$ volumes of sand and $2\frac{1}{2}$ volumes of coarse aggregate; this means that $2\frac{1}{2}$ barrels or 950 pounds of cement is used per cubic yard of concrete. In the manufacture of pre-cast pipe for the Winnipeg Aqueduct it was found necessary to use but one sack of cement to 3.8 cubic feet of mixed aggregate, or approximately 2 barrels or 700 pounds of cement per cubic yard of concrete. (The Canadian barrel weighs 350 pounds gross or 346 pounds net.) This small quantity of cement was found sufficient because of the very excellent grading of the mixed aggregate. The concrete is mixed to a quaking or jellylike consistency, which will easily flow into place when slightly puddled.

On the Winnipeg work, the concrete was mixed in batch mixers at each end of the manufacturing plant, and after being dumped into conical buckets was transported by traveling derricks to the molds. A simple ball valve easily and accurately controlled the flow of concrete from the buckets, which carried grout, concrete and

mortar equally well. Molds were filled simultaneously in pairs, one member of each pair being on opposite sides of the derrick track, which was located in the center of the manufacturing site.

When the concrete in the molds reached the top of the outer casing, a cast iron spigot ring was set and the spigot mortar deposited, tamped in place and the copper expansion joint set.

The mortar for spigots on this contract is made of 1 part cement to 2 parts sand. It is mixed to the same consistency as the concrete so as to obtain the same rate of setting and settlement, as nearly as possible. As the spigot mortar settles, more mortar is added until the settlement ceases, when the joint is finished.

Each expansion joint is mounted on a steel spider which remains in position until the concrete has set and the forms are to be stripped from the pipe. The spider is centered accurately by means of a pin and a hole in the center of the filling platform.

To maintain a constant and uniform rate of setting in the concrete, as well as to protect the concrete from the low night temperatures sometimes attained in Canada, wet steam was used in order to obtain a moist, warm atmosphere about the pipes. The steam mains were laid underground in a way to prevent excessive radiation as well as to place them out of the way. A riser connected each steaming set of five vertical jets with the mains. One of the jets was placed in the center of the concrete foundation so as to be in the center of the cast iron base and the other four jets were spaced equidistant around the circumference of the base, sufficient space being allowed for clearance between the jets and the edge of the base. To confine the steam to the pipes, canvas jackets and hoods were used, the jackets being suspended by hooks from an iron pipe ring supported on two hard wood arms which were raised above the copper expansion joint strip by hard wood blocks on each end of the arms. The jackets were laced vertically and a canvas hood placed over the top of the steam cover spider, the wood arms and the iron ring of the spider preventing the hood from resting on the light copper expansion joint. The hood was tied to the jacket by means of rope and rings, and the jackets were held snugly in place by rope run through eye-bolts secured in the concrete bases. The canvas steam covers were removed with the spider when the forms were stripped, and were replaced as soon as the casings had been removed. The steam was again turned on and the pipe steamed for three to four days.

Leakage tests on completed pressure conduits

LOCATION	DIAMETER	LENGTH OF LINE	PRESSURE HEAD	LEAKAGE	
				Per 1000	Per mile
	inches	*feet*	*feet*	*gallons*	*gallons*
Baltimore, Md.	108 and 84	8,700	82	1,494	7,888
Dallas, Tex.	36	14,000	70	121	639
Ft. Worth, Tex.	36 and 48	1,200 12,800	70	1,143	6,035
Seattle,* Wash.	42	8,000	135		

*The pipe line in Seattle was a trunk water conduit to operate under a head of 90 feet and every pipe was tested to 135 pounds pressure. Tests were made on short sections of completed line and the leakage was nil.

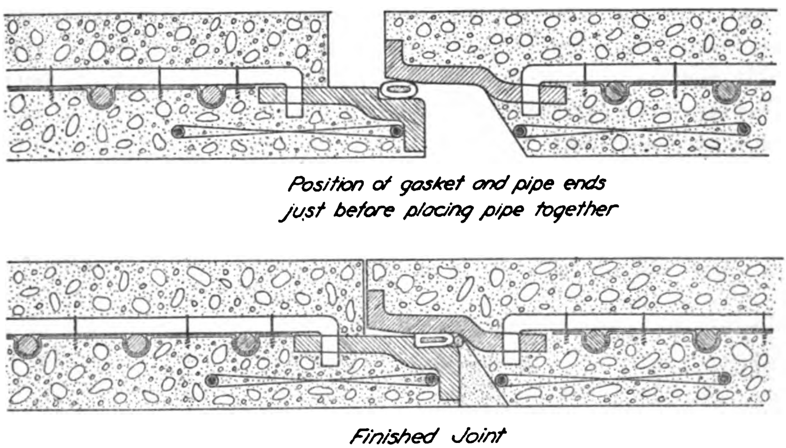

FIG. 2. NEW TYPE OF JOINT.

All that has been said heretofore refers particularly to the copper expansion joint type of reinforced concrete pressure pipe. There has recently been developed a new type of expansion joint, and at the time of writing this paper reinforced concrete pressure pipe 36 inches in diameter with this type of joint has been manufactured and tested with satisfactory results.

It is proposed to construct reinforced concrete pressure pipe 10 to 48 inches in diameter and 12 feet long, each section being provided with a cast iron spigot ring at one end and a cast iron bell ring at the other, the rings being cast integrally with the concrete. Figure 2 shows the joint. The faces of the rings which bear upon

the lead gasket will be accurately machined, providing a very true circular surface. The spigot ring is provided with a seat for the lead gasket, the face of which seat forms half of a dovetail, the object being to provide a greater thickness of gasket at the seat of the dovetail. This prevents the gasket being withdrawn when the pipe contracts or when the pipe is deflected.

The lead gasket consists of a lead pipe filled with compressed fiber and then flattened to an elliptical section, the proper length of gasket being turned to a circle, which is joined forming a ring. This ring is placed in the bell and the pipe is then ready to receive the spigot end of the next pipe to be laid. As the pipes are shoved home the lead gasket is changed from the elliptical section to a section which fills the dovetail space and the space between the dovetail of the bell and the outer face of the spigot. After this has been done a light rope of cotton or jute is placed and a weak joint filler of cement mortar is applied, filling the calking space. This space is provided in the event it should be necessary to calk the lead gasket joint. Such calking is not expected to be necessary.

SIGNIFICANCE OF BLACK SANDS IN FILTERS[1]

By J. E. Welker and C. C. Young

Regulations adopted by the Kansas State Board of Health under the Water and Sewage Law passed by the 1915 Legislature require weekly analyses to be made in the laboratory of the board of waters from all surface sources and semi-annual inspections of the water works by the engineers of the division of water and sewage of the board. This relatively close contact with the filter plants has brought up many topics of filter plant operation for discussion and solution, not the least interesting of which is the darkening of the sands.

Filter plant operators noted a gradual darkening of the sands in many of the plants. At first no thought was given to the phenomenon other than the fact that the beds were not clean at the time of observation, but it was found impossible to wash the sand back to its original color. Samples were submitted to the laboratory and analyses made which showed that the dark color was due to manganese and iron. The darker the deposit, the higher the percentage of manganese.

At Osawatomie there was the most striking change in the color of the sand. In a few weeks the color changed from a natural light yellow to coal black. Careful study of the basin and influent lines showed a growth of bryozoa or pipe moss. When these organisms died, the deposit of their sheaths showed a very high percentage of manganese. An analogy was drawn between this phenomenon and the fact that the muck lands of Florida, Hawaii and other places carry an extremely high percentage of manganese and it seemed perfectly plausible that the same principles of decomposition and deposition would be maintained in a filter bed that was allowed to become foul.

In most communities plants are built to supply much more water than is actually needed. Consequently, they are intermittently operated. The filters will be run for a few hours and be allowed to stand six or eight or even twenty-four hours without filtering again and without washing. This procedure is continued until

[1] Read before the St. Louis Convention, May 14, 1918.

such a loss of head results that no more water can be put through the filter. The filter is then washed. In every filter plant mentioned in this paper, there have probably been many periods of stagnation varying from eight to twenty-four hours.

In Meade County, Kansas, and elsewhere there have been found small beds of almost pure quartz sand, coated with a deposit similar to those that develop in intermittently operated filter plants. No

TABLE 1

Results of analyses of filter sands: grams in 10-gram samples

	RATE OF WATER	Mn_3O_4	YEARS IN BED	Fe_2O_3	Mn_3O_4 AND Fe_2O_3	OXIDES AND CLAY	DIFFERENCE, CLAY
Neosho River	*inches*						
Burlington	12	0.0030	4	0.0035	0.0065	0.0771	0.0706
Chanute	15	0.0076	4	0.0142	0.0218	0.3908	0.3690
Humboldt	15	0.0129	2	0.0214	0.0343	0.4594	0.4251
Council Grove		0.0683	3½	0.0071	0.0754	0.3470	0.2716
Verdigris River							
Independence							
Original		0.0007	4	0.0093	0.0100	0.0583	0.0483
Used		0.0070		0.0214	0.0284	0.2915	0.2631
Coffeyville	15.0	0.0172	4½	0.0092	0.0404	0.3169	0.2765
Cherryvale	12.0	0.0312	6	0.0214	0.0526	0.9930	0.9404
Walnut River							
Douglas	12.0	0.0061	3½	0.0017	0.0078	0.1206	0.1128
Winfield	7.5	0.0634	8	0.0214	0.0848	0.6042	0.5194
Augusta	9.0	0.2037	6	0.0178	0.2215	0.9459	0.7244
Marais des Cygnes							
Osawatomie		0.0298	2½	0.0172	0.0470	0.2876	0.2406
Mill Creek							
Washington	12.0	0.0580	3½	0.0071	0.0651	0.2550	0.1899
Impounding Reservoir							
Garnett	18.0	0.0240	3	0.0214	0.0454	0.3507	0.3053
Olathe	14.7	0.0141	3½	0.0050	0.0191	0.1084	0.0893
Shreveport, La		0.0095		0.0214	0.0309	0.2642	0.2333

one can say just how and where these beds were laid down but it is fair to suppose that the conditions were somewhat similar to that existing in a foul filter bed.

In making analyses, the sodium bismuthate method was used to make the determination of manganese and the iron was determined colorimetrically. The clay reported in the table was accreted with the deposit of manganese and iron oxides. It is fortunate that the

laboratory saved samples of the original sands that were introduced into the filter plants at the time of their construction. All of the sands returned negative results for manganese, with the exception of the sample from Independence, which gave 10 milligrams of the combined oxides.

Table 1 gives the results of analyses and a short description of each plant is appended.

Burlington. Installation test made May, 1914. New York Continental Jewell standard filter equipment; combined air and water wash. Wash water from distribution system at pressure of 50 pounds per square inch. Wash water valve opened to give rate of 12 inches vertical rise per minute. Considerable difficulty has been experienced with microscopic growth in basins and filters. General operation of plant good. Sand removed March, 1917, following trouble with filter bed. One manifold pipe found broken.

Chanute. Installation test made May, 1914. Pittsburg Filter Company standard equipment. Washed with water alone, furnished by centrifugal pump, giving a rate of 15 inches vertical rise per minute. Plant operation fair.

Humboldt. Installation test made May, 1916. Pittsburg Filter Company standard equipment. Filters washed with water alone. Wash water supplied from distribution system and valve opened to give wash water rate of 15 inches vertical rise per minute. Plant operation fair.

Council Grove. Installation made September, 1914. New York Continental Jewell Filter Company standard wooden tub filter construction. Filters washed with mechanical agitation. Wash water supplied from distribution system pressure. No reducing valve used on the wash water line and as a result excessive rates have been used, resulting in the displacement of the sand and gravel. In 1916 the filter beds were dug up and the gravel was found to be very much displaced and mixed with the sand, and many of the strainers clogged. February, 1918, the beds were again dug up and approximately 50 per cent of the strainers were found to be clogged. Plant operation good.

Independence. Installation test made May, 1914. Concrete filter construction, with ridged bottom under-drains using wire screen between gravel and sand. Wash water supplied from wash water tank, having a pressure of approximately 22 pounds per square inch at the inlet. Plant operation fair.

Coffeyville. Installation test December, 1913. New York Continental Jewell Filtration Company standard equipment. Combined air and water wash. Wash water supplied by centrifugal pump, giving a wash velocity of approximately 15 inches vertical rise per minute. Plant operation good.

Cherryvale. Installation test June, 1912. New York Continental Jewell Filtration Company standard equipment. Filter washed with combined air and water wash. Wash water supplied by centrifugal pump, giving a wash water velocity of approximately 12 inches vertical rise per minute. Plant operation good.

Douglas. Installation test made September, 1914. New York Continental Jewell Filtration Company standard equipment. Filter washed with com-

bined air and water wash. Water supplied from distribution system at a pressure of approximately 50 pounds per square inch. Variable rate of wash water. Operation of plant good.

Winfield. Plant installed 1910. Modified Greer filter construction, using combined air and water wash. Wash water supplied by separate wash water pump, giving a wash water velocity of 7½ inches vertical rise per minute. Plant operation variable.

Augusta. Installation test July, 1912. American Water Softening Company standard filter equipment. Air and water wash. Wash water originally furnished from distribution system; now furnished by separate wash water pump, which gives a wash water velocity of 9 inches vertical rise per minute. In 1916 the beds washed unevenly and mud balls were in evidence. Plant operation inconstant.

Osawatomie. Installation test December, 1915. New York Continental Jewell Filtration Company standard equipment. Combined air and water wash. Wash water secured from distribution system at 60 to 80 pounds pressure per square inch. On different occasions the wash water valve has been opened so that the wash water rate was excessive and the sand and gravel became mixed. The plant has had considerable operating trouble from microscopic growth in basins and filters. Plant operation variable.

Washington. Installation test October, 1914. New York Continental Jewell Filtration Company standard equipment. Filter washed with combined air and water. Wash water supplied by separate wash water pump, giving a wash water velocity of 12 to 13 inches vertical rise per minute. Plant operation variable.

Garnett. Plant installed 1908. New York Continental Jewell Filtration Company standard equipment. Filters washed with water only. Water supplied directly from distribution system, at a pressure of approximately 60 pounds per square inch at the manifold, giving a wash water velocity of approximately 18 inches vertical rise per minute. Sand replaced in 1915; in a very dirty condition in 1917. Plant operation poor.

Olathe. Installation test August, 1914. Pittsburg Filter Company's equipment. Air and water wash. Wash water velocity 14.7 inches vertical rise per minute. In January, 1918, the filters washed unevenly and several of the strainers were clogged. Operation good.

This investigation has not been carried to a point where it can be definitely stated that the darkening of the sand has any effect upon the efficiency of the filter, but there is a feature well worth investigation along this line because it seems that penetration of the bed is followed by this coloration. At the present time the only definite discovery is an ocular index of improper operation. This is something the small plant filter operator can be warned to look out for. If he finds that his sand is becoming dark, he should change his time or method of washing so that he will have no fouling or penetration of the bed.

MEMORANDA OF OFFICE RECORDS[1]

BY A. W. CUDDEBACK

The office records of the location of service pipes, valves, hydrants and distribution mains of the Passaic Water Company are about as simple as can be devised, consistent with giving the information necessary and useful for the proper recording of such structures.

Service pipes. Service pipes are given a serial number, which is also the number that goes with the account, and these numbers have been running continuously from one up since the business was started. Where there are several services pipes supplying one property which comes under one account, they have the same number.

The accounts are indexed on the ledger cards under the street number and name of the person paying the water rent.

The record of the service is entered on a No. 9518 Library Bureau card, which is practically 3 by 5 inches in size. The front of this card shows the serial number; street number; name; size of tap in main; size of service pipe; size of main; and gives a measurement of the location of the corporation cock, which refers to the lot line, the building or curb line. It has the date on which the connection was made; the kind of material; and the name of the foreman putting it in; whether there is a curb shut-off and how far laid.

The reverse side of this card has printed upon it a diagram of a city block with streets on four sides of it, on which is made a sketch of the property, indicating the building; the main in the street; and the service pipe. On this the reference measurements are entered again, showing to what point they refer. The four streets bounding the block are named so the property can be definitely located.

If the service pipe is renewed at any time, the detail of the renewal is entered upon the card, or if necessary, a new card is made, giving the additional information required by the change.

When a service pipe is abandoned for any reason and is not at that time replaced with another service, the number formerly

[1] Read at the St. Louis Convention, May 16, 1918.

applying to that service is used for some other service, thus avoiding a lot of dead numbers.

It is very easy to get the proper information for entering on this card, because the company lays its own service pipes and has been doing so for the past 20 years. Where private plumbers are allowed to make service pipe connections, proper cards should be furnished them, on which to record the information desired to be kept for reporting to the water office.

For the purpose of recording the location of services not on rectangular blocks, cards are used with the reverse side blank, in order that a sketch showing the exact conditions may be made.

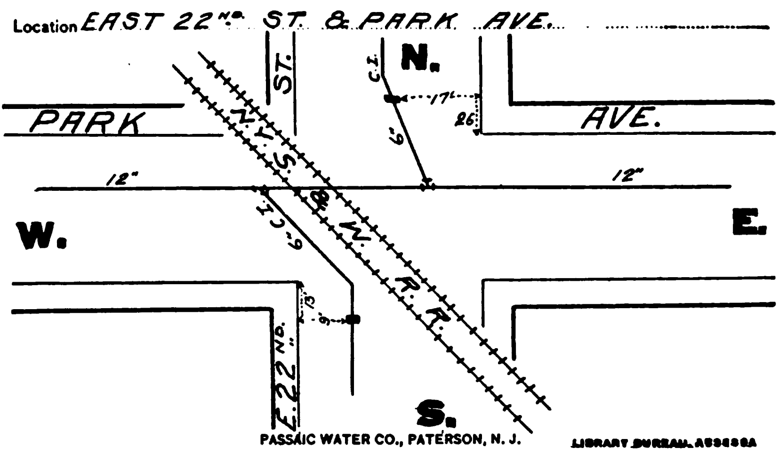

FIG. 1. FRONT OF VALVE RECORD CARD

Valves. Valve cards are exactly the same size as the service pipe cards. The front of the card in this case, however, shows the sketch, which has four blocks with two streets between, figure 1. The pipes are sketched in the streets in both directions. The cardinal points are marked with a rubber stamp. The location of the valve is indicated, and the measurements, referring in almost all cases to the curb, are entered on the sketch. The names of the streets are marked.

The cards are indexed according to streets and run consecutively in one direction on the street. They are cross-indexed by entering a card for the cross street on which is put only the name of the street.

On the reverse side are printed locations for four valves, figure 2. Locations are made by giving the distance north, east, south or west, from the curb lines.

As in the service pipe cards, for special locations, blank cards are provided on which the sketch can be made.

Valves are also given a number, which number is consecutive with their installation.

Hydrants. No special card is used for hydrants. The record of the hydrant is kept in a book, which gives the serial number of the hydrant; the street on which the hydrant is located, the street on which the hydrant faces being mentioned first; the date it was installed; make of the hydrant; and the water pressure; also whether

Size 6" Location EAST 22ND ST. S. OF PARK AVE. No 1852
13 ft — in S from the S Curb of PARK AVE. ~~St.~~
9 ft — in E from the W Curb of EAST 22ND St.

Size 6" Location EAST 22ND ST. N. OF PARK AVE. No. 1853
26 ft — in N from the N Curb of PARK AVE. ~~St.~~
17 ft — in W from the E Curb of EAST 22ND St.

Size Location No.
ft in from the Curb of St.
ft in from the Curb of St.

Size Location No
ft in from the Curb of St.
ft in from the Curb of St.

FIG. 2. REVERSE OF VALVE RECORD CARD.

the hydrant is gated or not. A card index is kept of this book by street intersections so that the book can be readily referred to.

Distribution mains. A field book with pages 5 by $7\frac{1}{2}$ inches is kept of all distribution main installations. This book is of the ordinary size used by engineers for notes, and is ruled in small squares.

The necessary information for this book is sketched in pencil when the installation is made. A complete sketch is made showing the street lines; location of pipe with reference to these lines and proper measurements; location of valves, hydrants, branches and specials is also indicated; dead ends; kind of material used; name of foreman making the installation; character of the digging; depth to which pipe is laid, as shown in Fig. 3.

There also appears on this page a symbol which shows, when checked, that the information given here has been recorded in its proper place, i. e.,

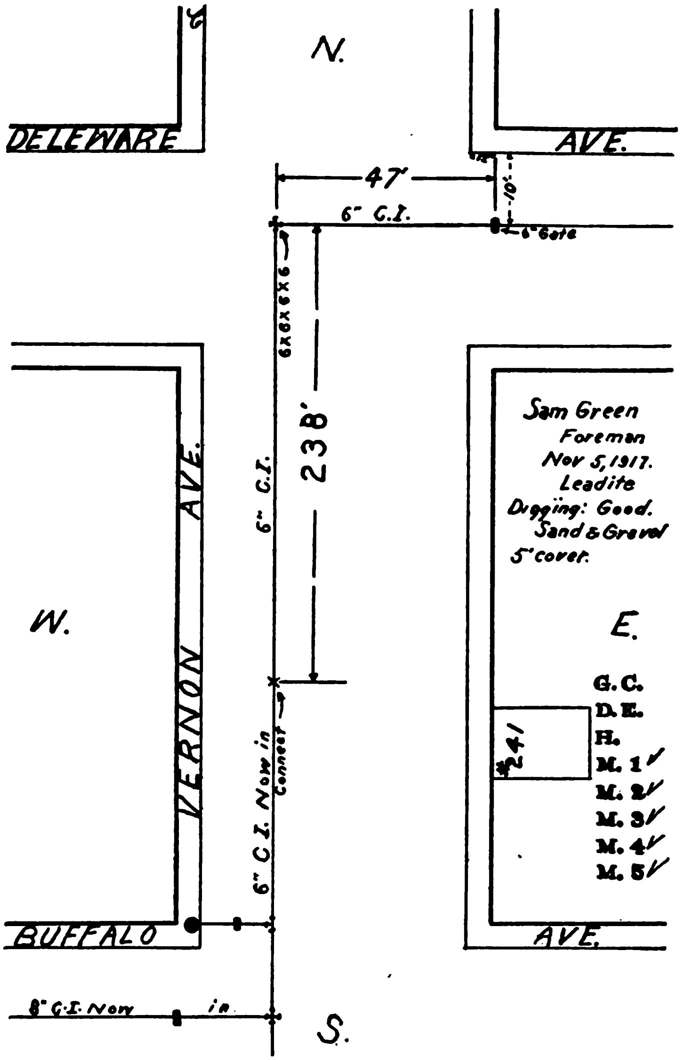

FIG. 3. PAGE FROM DISTRIBUTION FIELD BOOK

G. C. means gate card, and when checked that the information has been placed on the proper card and filed.

D. E. means dead end, that the proper record has been made of the dead end on cards kept for this purpose.

H. means hydrant, and that it has been recorded in the proper hydrant book.

M. 1, M. 2, M. 3, M. 4, and M. 5 indicate that the information on this page has been recorded on Maps 1, 2, 3, 4, and 5. These maps are large maps on a scale of 400 feet to the inch, which show the entire distribution system, with location of hydrants, valves and street mains indicated according to the nomenclature adopted. Maps of this kind are kept in various convenient places for reference, as in the working office and in the office of the superintendent and engineering department.

The book is indexed by streets with reference to the book number and page number on which the original sketch appears, and kept properly filed. No other detail record of main locations is kept. It has been found that all the records necessary or desirable can be kept in this way. As much or as little detail as desired can be entered in this book.

None of the records, either in the books or on cards, is drawn to scale.

Maps showing the distribution system as a whole, are usually made with the width of the streets exaggerated so that the piping system stands out as the main feature on the map. It does not take an expert draftsman to do any of this work. Anybody who is a fairly good letterer and can use a straight line pen and is neat, can do the work satisfactorily.

WATER POLLUTION AND FISH LIFE[1]

By Victor E. Shelford

The United States Fish Commission is urging the public to eat fish—to make every day a fish day. This was once the case. In a great strike of apprentices in the early days of the republic one of their chief demands was that they receive salmon only three times a week. The richness of the fish supply of our eastern states in the colonial days and early days of the republic can scarcely be appreciated. One author said of the shad in the Susquehanna and Delaware Rivers:

> They came in such vast multitudes that still waters seemed filled with eddies, while the shallows were beaten into foam by them in their struggles to reach their spawning grounds. They swarmed every spring from mouth to head waters of every stream from Maine to Florida.

Shad was an important food fish in the early days of the nation; they were eaten fresh and smoked, and were salted for winter use. During the spring runs people traveled long distances to shoal waters to obtain their winter's supply. Along the Illinois river many years ago the buffalo fish was the chief marketable species. These were caught by farmers, fishermen and others during the breeding season and shipped by boat, principally to St. Louis. No ice was used. The fish were frequently thrown away because they spoiled or the market was overloaded.

Perhaps without mention of these facts, the author's remarks about fish would not mean very much. Americans have been very careless with the fish resources in this country. There was over-catch. Then pollution of water by wastes from manufacturing plants and by sewage of cities completed the work of destruction already started by heedless fishermen, but the pollution of the water is far more serious than over-fishing because it destroys the

[1] Read before the Illinois Section, April 16, 1918. A more complete discussion of the nine topics mentioned in this paper 20 being published in the Bulletin of the Illinois State Laboratory of Natural History, Vol. xiii; Art. 2.

possibility of easy recovery. It is well to take stock of our knowledge now under pressure of numerous problems demanding immediate solution because of the great war. In connection with the manufacture of munitions, the proposed recovery of grease from sewage, and other activities, some of the most dangerous effluents result, giving us special war problems. The dangers to fishes are increased with the greater need to conserve them. Means of measuring the harm which pollution will cause are needed at once. Our knowledge is incomplete and not organized for the purpose. While it is not difficult to formulate a number of important questions to keep in mind in dealing with water pollution, the answers to most of them demand much investigation. However, the author will outline nine points very important to consider in our efforts to safeguard fishes.

1. First of all, some of the wastes introduced into the sea, lakes and streams kill fish and other animals useful for food. Tests of the toxicity of sewage and industrial wastes must be made. In doing this it is not sufficient that one take any fish or other animal he picks up. A fish that is representatively sensitive must be used. For this purpose use young suckers—either the red horse or common sucker. They are not less resistent than some of the plants and animals which constitute the food of fishes and are sufficiently sensitive to afford a good criterion of danger to fishes in general. Among marine animals either fishes or shrimps may be used.

2. There is always a most sensitive period in the life of a fish or other useful animal. This is usually in the young stages. In the case of the clam worm the egg at the time it is laid is about twenty times more resistant than the young larva. Some fishes appear to be most sensitive at the time of hatching and others in the egg stage; this stage may be a hundred times more sensitive than the adult. The most significant thing to know about poisons is the least fatal concentration to the most sensitive stage. In general one should use the youngest test animals he can get, for example the youngest suckers.

3. Conditions in streams and other bodies of water vary; the concentration of the polluting substance should be known. The minimum flow of a stream usually gives the greatest concentration. The summer low-water conditions are dangerous because of little flow and high temperature which increases toxicity; the winter low-water because of slow flow and ice which prevents aeration.

Perhaps something might be done, such as forcing air through the effluent near the point where the pollution is introduced to reduce this danger during critical periods by increasing oxygen and removing carbon dioxide.

4. The removal of constituents and the results of treatment of various polluting substances must be fully analyzed. It is necessary to know the results of treatment of sewage, industrial wastes, etc., in terms of their effects on useful aquatic animals. If coal tar wastes are partially recovered it is necessary to know whether the residue is still toxic. Experiments have shown that nearly all constituents are, and hence any residue will be almost certain to be poisonous. Effluents which result from the Miles acid process of sewage treatment must receive special consideration, because acid effluents such as result from it are very poisonous, particularly those resulting from the use of SO_2. Such questions as how much acid will the water neutralize, how much CO_2 is liberated, and the like, must be answered. Also which is the more toxic, H_2SO_3 or H_2SO_4? From existing knowledge it appears that sulphites and acid sulphites are far more toxic than sulphates.

5. The substances which are introduced into the water not only affect fishes directly but also act through effects on the bottoms on which eggs rest. Lake Michigan once produced numerous white-fish. The number of whitefish has been greatly reduced. The reasons are not only over-catch but also the covering up of breeding bottoms with a large amount of sawdust and other rubbish which makes the spawning grounds useless. Some of this bottom can never be recovered, at least, not for a long time.

6. The reaction of the animals demands attention. Both fresh water and marine fishes react negatively to acids, i.e., they turn back when they encounter them. Freshwater fishes will not enter any but the weakest concentration; marine pelagic fishes select alkaline water. In the fourteenth century, about the time the Baltic towns of the Hanseatic League, which depended upon the herring industry, were at their most prosperous stage, herring began to leave the locality and are supposed to have migrated to the North Sea. Herring were at one time very abundant in places which are now practically deserted. Herring invariably select a slightly alkaline water and avoid acids which result from contamination. The New Jersey Mosquito Commission finds that the acids thrown into the coast waters by munition works repels the killifishes on which

they depend to keep the mosquitoes down. There is also a different danger from other substances, especially organic compounds, in that fishes swim into solutions of these and after short stays avoid pure water and die.

7. The time it takes a body of water to recover if it has once been depleted must be considered. It has been shown that a whole association of plants and animals must re-develop in places of this sort. If a pine forest is destroyed by fire, fire weeds grow up followed by cottonwoods or birches and after a long time pines again. A similar slow process must take place in depleted waters.

8. There is danger from decisions made without investigation of a particular case. One important reason for this is that poisons are in some cases rendered much less toxic by salts in solution in the water polluted and in other cases they are rendered much more toxic by the salts present.

9. We need a new system of bookkeeping in dealing with these matters. The value of a waste is not simply the value of the products which may be prepared from it after the cost of recovery has been deducted, but from the value must be substracted all damage which the untreated waste does to water supply, fisheries, etc. That is, the needs of the entire community must be considered, and not merely those of a few individuals.

WATER TREATMENT AT COUNCIL GROVE, KANSAS[1]

By Louis L. Tribus

In March, 1915, the Association published a brief paper descriptive of the then recently remodeled water works station at Council Grove, Kansas, the special item of current interest being that portion of the plant treating the raw river water. The feature of novelty lay in the plan for successive application of dissolved coagulant, as the water passed from one part of the system to another. The use of coagulant could be very closely regulated as river conditions required and as the water exhibited its very varying characteristics and behavior while going through the different original stages from sometimes serious foulness to clear and safe potability.

After three years of operation, it may be of interest to note some of the results secured under the peculiar difficulties that have had to be met.

The Neosho River has but a limited watershed; it flows largely over a rocky bed, traversing a black soil belt but sparsely wooded. The general region is subject to sudden and violent storms which are without regularity as to season. These conditions produce high floods and varying turbidities, at times well over 5000 parts per million. How much more than that is not recorded, for the local testing apparatus has no higher range. The river flow varies from almost nothing (a slight spring supply) to an over-abundant maximum, running from 7 to 15 feet in depth over the dam, having a crest length of 100 feet or over.

Alkalinity ranges from a minimum of 48 to a maximum of 365, decreasing as the river rises.

With the silt burden come also varying colloidal troubles.

The water temperature fluctuates from a minimum of 33° to a maximum of 86°.

The bacterial content has naturally a very wide range, due to the nature of the watershed and varying character of the flow of the river.

[1] Read at the St. Louis Convention, May 14, 1918.

Algae are prolific at times in the summer season when the river is low; copper sulphate is used sparingly, but with success, in the lower reservoir. The natural quality of the water at low river stages is quite fair, although high in permanent hardness, which lessens somewhat as storm waters raise the river level.

It can be well imagined that with these characteristics, the treatment problem is one that can not be left to unintelligent handling.

The two successive superintendents of the plant have taken very great personal interest in its operation, endeavoring constantly to not only secure the delivery of an effluent that would be as near perfect as possible, but to reduce costs at the same time.

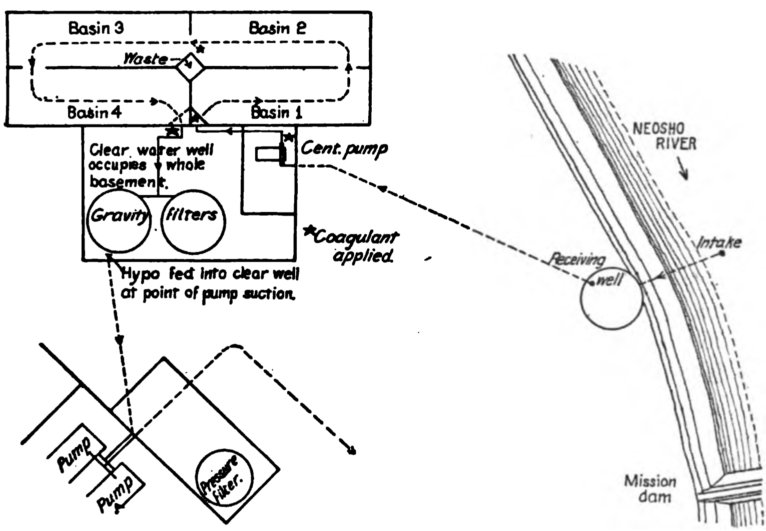

FIG. 1. COURSE OF WATER THROUGH PURIFICATION PLANT

The water flows from the river into a reception well in which considerable deposition of suspended matter takes place. From this a low-lift centrifugal pump raises it to the first of a series of four basins. At the pump it can receive a first dose of liquid sulphate of alumina, which becomes pretty thoroughly mixed in the discharge pipe before entering the first basin near the bottom through a triangular down-chute.

At this point a second dose can be given. The water then passes the length of basin 1 and through a low-level submerged opening

enters basin 2. Passing through this, a third dose can be added just as it reaches basin 3 through a second submerged opening, placed at a higher level than that between basins 1 and 2. Flowing through basin 3 and into basin 4 at a still higher elevation, though still submerged, the water finds, at the farther end, the inlet to the filters, where a fourth dose of coagulant can be added.

It was found in the early stages of experimenting that in a turbid stage of the river the whole charge of coagulant at the pump or at basin 1 alone, was ineffective, for the globules of aluminum hydrate became coated with mud long before full service had been rendered, consequently practically untreated water passed to the filters. If, however, the charge was sub-divided and applied at points as observation showed necessary, each reached the water at a time when additional treatment was needed, and consequently before flowing upon the filters a large proportion of the suspended matter had been thrown down. There are cross-wall baffles in each of the basins which exert some influence in checking flow and causing deposition of solids.

The relative deposition of solids in the different basins under different combinations of treatment indicates very clearly the value of successive and cumulative attention. Cleaning has not been as systematic as could be desired, so the quantities of accumulations removed could not well be compared with the rates of flow and coagulant used, as it would be interesting to learn and may some day be studied. The gross use of coagulant in the sum of the separate doses has nowhere nearly equalled the quantity that would have been needed with the raw water treated at but one point.

Very perplexing in the early operations was the experience with large doses of coagulant. It seemed as if the turbidity would not yield; apparently no floc formed and the filters soon became choked. Then suddenly, action would begin and all would go satisfactorily and the results could thereafter be secured with very much smaller doses.

Temperature and alkalinity changes also exert a decided influence upon the purifying action, though studies have not yet been sufficient to standardize the treatment and reach definite conclusions.

It has been impossible, for financial reasons, to employ a chemist regularly, so that operations, other than those determined by turbidity and alkalinity, have depended upon the operator's judg-

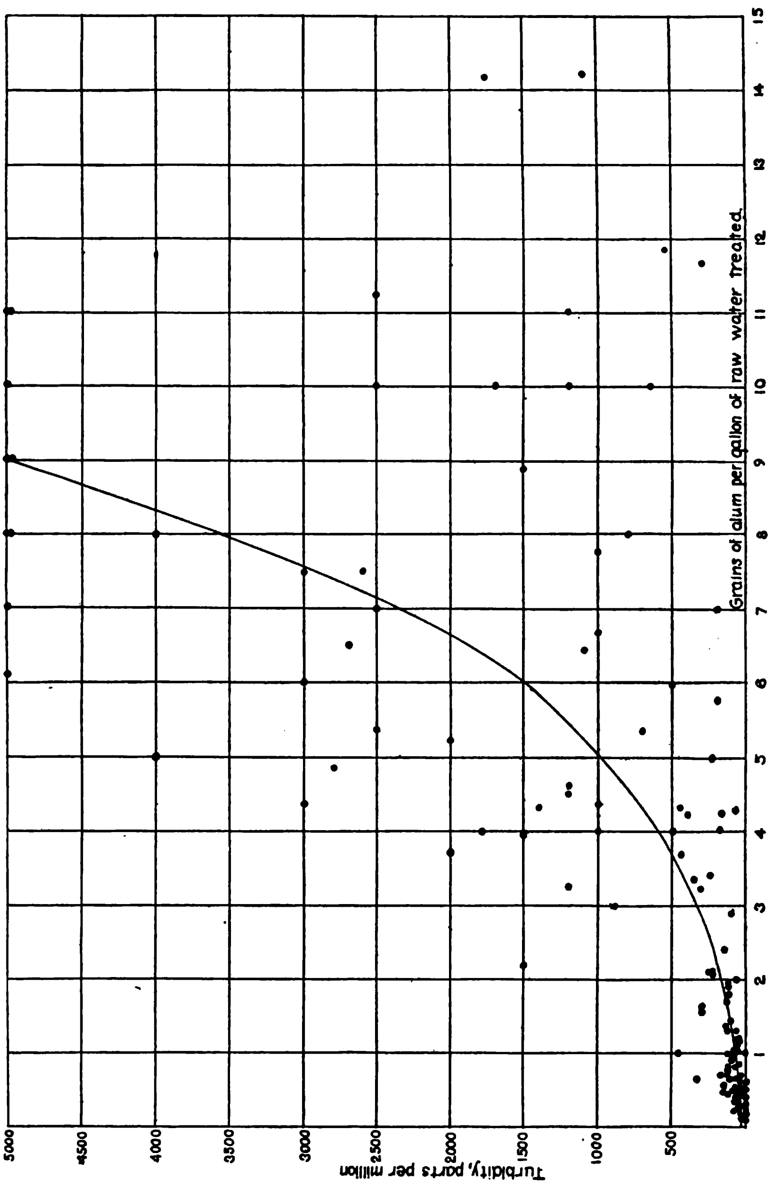

FIG. 2. 150 TYPICAL DAILY READINGS; TURBIDITY AND ALUM

ment, which has been largely controlled by the show of floc in the basins or on the filters and of course by the appearance of the filtered effluent.

Just as the water is drawn from the clear well for delivery by the main pumps into the city system, it receives dissolved hypochlorite, to the extent of 2 to 2½ pounds per day (dry chemical) for the 250,000 to 350,000 gallons of water pumped or about 10 pounds per million gallons ordinarily. This renders the water practically sterile, though the preceding operations remove the bacteria to a very satisfactory degree.

Weekly samples have been sent to the headquarters of the State Board of Health at Lawrence, where regular analyses are made with a view particularly to noting the presence of pathogenic bacteria and the values of turbidity and alkalinity. The reports received following such examination serve as a fair guide to the superintendent and give him a very good idea as to his success in handling the plant, confirming his own observations or causing him to use greater care if danger is indicated.

In the earlier weeks of operation following construction, the use of sulphate of alumina sometimes was as high as 20 grains per gallon of water pumped, but during 1916 and 1917, even with several periods of very high turbidity, the maximum was but 11 on one occasion and 9 on another; otherwise nothing above 7 in any of the flood periods, while the usual total rate has been considerably less than one grain per gallon.

With the exception of a few single days when the turbidity in the final effluent reached 30 parts per million, it has normally been zero. The successive improvement of the water, basin by basin, has very greatly eased the work of the filters, and hence in turn saves a large use of filtered water for back washing. The filters are of the open gravity type, the washing being aided by agitation with rotating stirrers. The wash-water pressure has been too variable for the best results, but a regulating valve is to be installed and perhaps a meter, so that future betterment should follow.

Upon the official tests of the plant, as well as in later operations, the bacterial removal by the basins and filters proved very satisfactory, through as before mentioned, as a final safeguard hypochlorite is used in small quantity.

The State Board of Health began making its tests in July, 1915; out of 102 reports since then received, 85 stated the water to be in

The test required for the filtered water shall be a reduction of bacterial content of at least 98 per cent from the content in the raw water, except that when the total number of bacteria is less than 3500 per cubic centimeter in the raw water, the filtrate must not contain in excess of 75 per cubic centimeter.

TABLE 1

Bacterial reduction in Council Grove treatment plant

DATE OF REPORT	BACTERIA PER CUBIC CENTIMETER		DATE OF REPORT	BACTERIA PER CUBIC CENTIMETER		DATE OF REPORT	BACTERIA PER CUBIC CENTIMETER	
	Raw water	Fil-trate		Raw water	Fil-trate		Raw water	Fil-trate
1915			*1916*			*1917*		
July 22	5,000	750	May 8	5,000	25	Mar. 19	80	45
July 31	3,000	120	May 12	300	60	Mar. 23	120	50
Aug. 5	2,000	50	May 20	1,900	310	Apr. 3	40	20
Aug. 13	1,200	30	June 3	21,000	60	Apr. 9	60	15
Aug. 19	82,000	22	June 16	2,000	60	Apr. 13	50	30
Aug. 30	4,000	100	June 26	6,000	30	Apr. 27	3,710	80
Sept. 4	3,000	75	July 6	600	460	May 7	1,360	20
Sept. 9	460	130	July 14	500	10	May 18	600	11
Sept. 18	450	15	July 20	1,900	70	May 25	450	18
Sept. 27	65,000	16	July 28	300	10	June 7	15,000	65
Oct. 6	92,000	42	Aug. 3	300	150	June 11	10,000	100
Oct. 11	27,000	410	Aug. 19	4,000	1,000	June 21	150	50
Oct. 15	300	25	Aug. 26	1,400	400	June 28	300	5
Oct. 22	70,000	30	Sept. 2	1,400	150	July 10	150	25
Nov. 2	1,900	26	Sept. 9	900	14	July 13	2,500	40
Nov. 8	3,100	64	Sept. 15	2,000	200	July 18	400	10
Nov. 12	1,600	30	Sept. 23	250	15	July 28	600	60
Nov. 22	4,500	25	Sept. 30	1,600	20	Aug. 4	1,500	150
Nov. 29	420	16	Oct. 7	90	15	Aug. 9	1,900	175
Dec. 4	200	15	Oct. 13	150	6	Sept. 5	1,800	8
Dec. 13	400	70	Oct. 20	200	16	Sept. 15	15	1
Dec. 17	1,400	25	Nov. 4	900	35	Oct. 6	750	550
1916			Nov. 11	500	30	Oct. 15	700	5
Jan. 17	3,000	50	Nov. 17	2,000	10	Oct. 20	200	9
Feb. 3	11,000	120	Nov. 24	800	90	Oct. 25	1,900	5
Feb. 11	40,000	35	Dec. 18	630	19	Nov. 3	1,000	8
Feb. 21	4,100	130	*1917*			Nov. 9	650	15
Feb. 26	1,400	25	Jan. 10	3,400	200	Nov. 16	900	125
Mar. 7	6,300	80	Jan. 15	1,400	290	Nov. 24	600	20
Mar. 13	250	100	Jan. 26	180	15	Dec. 3	1,000	50
Mar. 18	900	30	Jan. 28	400	220	Dec. 7	500	40
Mar. 23	1,000,000	840	Feb. 10	80	30	Dec. 27	225	90
Apr. 13	500	50	Feb. 17	70	20	*1918*		
Apr. 17	2,500	120	Feb. 23	150	26	Feb. 1	250	5
Apr. 23	850	225	Mar. 5	90	60	Feb. 14	450	55
May 1	1,500	800	Mar. 12	50	30	Feb. 18	150	15

"excellent," "very good," "good" and "fair" condition. Of the remaining 17, only two condemned the water, the others, though reporting "poor" rather raised question as to details of treatment, as the best results were not being secured. The bacterial count varies very greatly in the raw water and colon bacilli are usually indicated. The Board of Health makes its tests usually of the raw water and the finished effluent as taken from a service tap at the station. The original acceptance test of the filters was made subject to its approval.

The contract paragraph concerning bacterial removal is repeated on page 443, so that it may be compared with the results of the 2¾ years succeeding, as reported by the chemists of the Board.

Of the 105 bacterial reports, 81 show results handsomely within the test conditions, and but few of the others indicate any special deficiency in action. At times of heavy turbidity, when bacterial count runs specially high, the operations have been signally efficient; this indicates, perhaps, more special care in operation, due to the difficulty in securing a clear filtrate.

Taken as a whole, therefore, without a resident chemist, with several changes of station engineer and assistant, the breaking in of inexperienced men each time, and during quite a portion of 1917 with a superintendent in ill health, the showing is quite favorable to the working of the plant.

In a few tests which have been made, the percentage of successive betterment through treatment in the basins and the filters has been very interesting, but no consistent regular record has been kept, due to lack of sufficient time of the superintendent or engineer.

The operation of the plant as a whole has abundantly justified its design, and responds effectively to good care; though the filter strainers clog rather more than is desired and may have to be changed in type before long.

The diagrams illustrating this paper, other than figure 1, a plan showing course of the water from river to consumers, are made up from typical daily notations of turbidity, alkalinity and grains per gallon of sulphate of alumina used in the treatment.

From 1100 observations recorded during 1915 to 1917 inclusive, 150 have been selected, regardless of season, so as to cover so far as possible several readings at each rate throughout the whole range of variation.

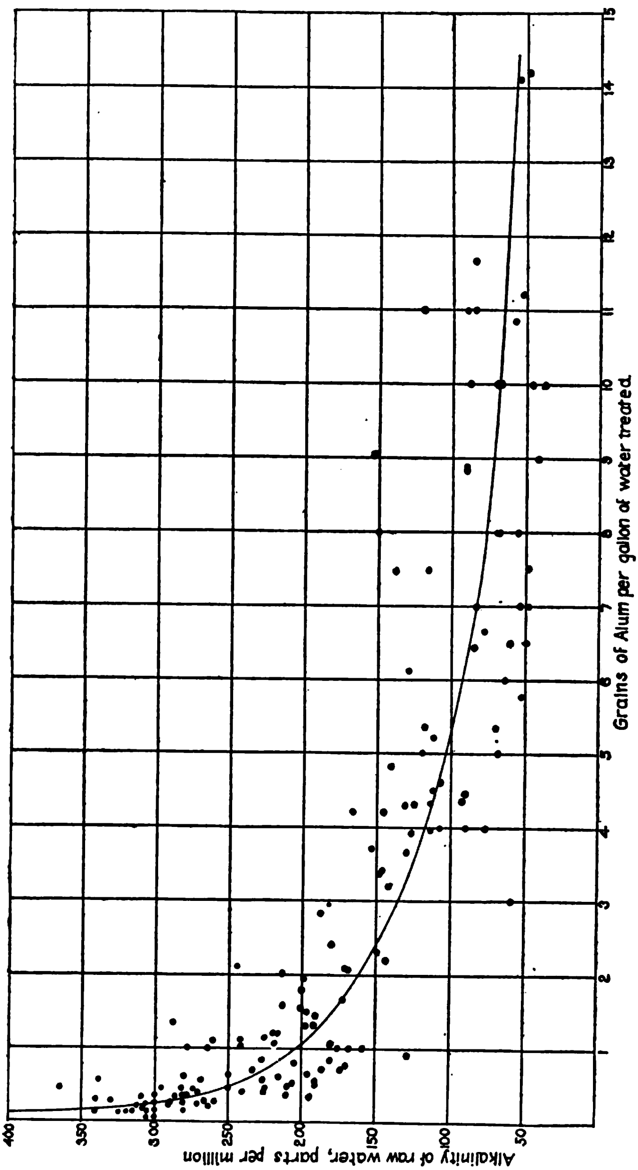

FIG. 3. 150 TYPICAL DAILY READINGS; ALKALINITY AND ALUM

The diagram showing "turbidities" compared with "grains of alum," figure 2, does not indicate clearly any particular law, though a suggestive curve, is shown, more based on general knowledge of the plant than determined from a close study of the turbidities. This is not surprising, for most of the turbidity is caused by heavy suspended matter carried by the high velocity in flood stage and quite ready to settle when brought to reasonable rest.

Occasionally a bad colloidal condition obtains, when the hydrate of alumina finds hard work to perform, but there has been little opportunity to study it carefully as a separate problem.

The diagram comparing "alkalinity" with "grains of alum," figure 3, indicates very nicely a relationship that permits the selec-

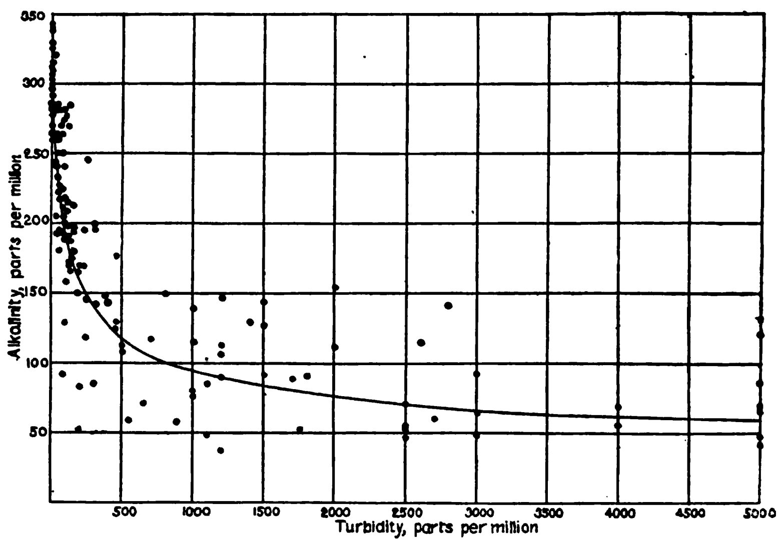

FIG. 4. 150 TYPICAL DAILY READINGS; ALKALINITY AND TURBIDITY

tion of a fair, smooth curve to represent normal working, except when some special river condition upsets all theories and gives several hours of perplexing activity and experiment.

The remaining diagram, comparing "alkalinity" and "turbidity," figure 4, indicates a chance for a fairly good curve, but one not specially conclusive in nature, and possibly to be changed materially as further observations are made.

The higher alkalinities prevail generally in the winter season, during the lowest river stages, when turbidities would naturally not

run high, even with fair-size floods, for frozen lands do not yield so readily to erosion.

In all of the 150 records taken for plotting, the effluents were reported as having zero turbidity.

It is rather an interesting commentary on human nature, however, that while the water company has furnished safe filtered water for twenty years and brilliantly clear, sterilized, filtered water for three years, there are still many residents who hold to the rain tanks with roof washings, and shallow back-yard wells. Rates have been held at the low figures established 30 years ago, based on the low schedules of the city of St. Louis. A change, however, must shortly be made, so as to give more adequate return upon the investment in use.

It is often in the smaller plants that some of the most perplexing problems arise for the water works engineer to solve. This plant has been very interesting to the author, for it has illustrated many of the difficulties of operating a water treatment system and well repaid his occasional trips to examine its workings, suggest improvements, and generally consult face to face with the operating officials, during 20 odd years of advisory service.

RECORDS OF INSTALLATION AND MAINTENANCE OF WATER MAINS AND APPURTENANCES OF THE MUNICIPAL DISTRIBUTION SYSTEM OF THE CITY OF NEW YORK[1]

By William Hauck

The following is a brief description of the procedure followed and records made, in connection with the installation and maintenance of water mains and appurtenances of the municipal water supply system of the city of New York. This work is under the Bureau of Water Supply of the Department of Water Supply, Gas and Electricity.

Requests for mains are noted on forms provided for that purpose and generally spoken of as project sheets. The outlines of the locations with the existing and proposed mains, etc., are shown in sketches at the top of these sheets and all the data as to requirements and conditions are filled in, using spaces provided for the purpose. Special local information is noted under "remarks." These sheets take a prescribed course and are eventually combined and included in a contract or filed for future reference, depending upon whether they are approved or disapproved. Complete record is kept of these sheets in books provided for that purpose.

When necessity requires it, an order is issued to the Division of Investigation and Design to prepare a contract for laying mains, etc., in certain locations. The plans which were prepared in accordance with the project sheets are then combined and a title page added. The bids for the work are received on the percentage basis, i.e., the contractor is required to bid a percentage of the unit prices fixed by the engineer for each item. The bids are noted for general information on tracings known as "bid sheets," giving the names of the bidders, together with the unit prices estimated and bid. When the stipulated preliminaries are fulfilled the borough engineer is directed to see that the contract is executed. In the case of a furnishing, delivering and laying contract, three copies of a requisi-

[1]Read before the St. Louis Convention, May 16, 1918.

tion covering the material required are prepared; one is sent to the contractor and the other two to the inspection division, which in turn, issues orders to its foundry inspectors to inspect the cast ings during and after manufacture. Reports of these inspections, in duplicate, giving the numbers and weights of castings (R being used to indicate rejections) are forwarded regularly, one copy being filed in the inspection division and one with the engineer in charge of the contract.

Progress on the contracts is noted on the print or prints kept for that purpose, the pipe, etc., laid being indicated by marking with red crayon. A plan or plans is sent to the foreman in whose district the work is to be done, and he is at the same time informed as to the engineer in charge of the work and from whom he is to take orders as to shut-offs, etc.

Inspectors assigned to the field work keep field books, noting therein daily all work done, force employed and sketches showing details of connections. All numbers and weights of castings received or borrowed from or sent to the department yards are noted in these books and later transcribed on daily report forms provided for this purpose and delivered to the borough headquarters.

The engineers in charge of field work keep records of pipe laid, drawn to scale on cross-sectioned cards, 5 by 8 inches, one card for pipe, castings, etc., and a corresponding card for trench excavations, showing the location of the pipe in relation to the curb, the cover on the pipe, class of excavation, pavement and any other details that are essential in connection with properly preparing the estimate for payment for work done.

A monthly report of the work done is prepared showing the progress, which is also graphically shown by plotting a curve, a required-progress curve having been previously established in accordance with the time allowed for the completion of the contract and estimated cost, etc.

All castings are numbered and weighed at the foundry and these weights and numbers are used for identification of these materials until they are placed in the work or delivered at one of the designated department yards. Loose leaf sheets, 13 by 16 inches, are used for keeping records of cast iron material and, also, for working out from the field sheets the remaining items of the contract. The ruling is the only difference in these sheets. The casting sheets are ruled vertically and horizontally and rubber stamps are used to

designate various materials. The remaining items are figured on sheets ruled horizontally only, no rubber stamps being used.

Approximate estimates of work done are prepared from time to time, but not oftener than once a month, and are forwarded on sheets especially prepared for the purpose.

Notes on pipe, etc., installed are copied by the draftsmen on a map, on a scale of 1 inch to 300 feet (known as the wall map), on 27 by 40-inch tracing maps having an approximate scale of 1 inch to 100 feet and in turn copied on field and headquarters maps of emergency engineers, on maps of the Water Waste Investigation force, the maps used by all foremen, and also on the maps which are carried on each repair vehicle.

When all of the work on a contract has been completed, accurate drawings, on a scale of 1 inch to 40 feet, are prepared as a permanent record.

The city is divided into repair districts, the size of the district depending on the maintenance involved. The clerk in each headquarters sends daily to the borough main office a copy of his blotter. Every individual piece of work done by the repair company force is designated by a job number. Weekly he sends a report of work done that affects the maps. This is checked with his daily reports, and maps and records corrected accordingly. In addition to the blotter the clerk keeps a book, known as the complaint record, in which complaints are recorded, the final disposition being noted.

The records of taps inserted and also plugs used to replace taps are kept on $3\frac{3}{4}$ by 6-inch cards; all details as to the location with reference to curb and house lines, size of the mains, depth of cover on the main, plumber's name, tapper's name, etc., are noted. The same cards are used to record the house service inspections.

A staff of draftsmen and clerks is continually employed in keeping up to date the numerous maps and various office records. The district companies are visited regularly by a junior draftsman in order to keep the maps up to date within a week. The office maps are kept up to date daily.

THE PROPERTY OF CERTAIN WATERS WITH REFERENCE TO THEIR ACTION ON METALS[1]

By S. W. Parr

The waters of this region have certain peculiarities which show themselves more especially in steam generation and steam heating appliances. For this reason their properties and behavior have been largely overlooked. These waters are classified as alkaline, meaning thereby that they have present free sodium carbonate or more than enough sodium to unite with the sulphate, chloride, and nitrate radicals or ions. There is left, therefore, only carbon dioxide, CO_2, to unite with the remaining sodium and also all of the calcium, magnesium and iron. Such waters have only temporary hardness, there being no sulphates of calcium or magnesium.

Now it so happens that the Champaign-Urbana water supply was the first water of this type to come into use or, indeed, to the notice of water chemists, who were at first rather reluctant to report free sodium carbonate in conjunction with carbon, magnesium and iron, as being an incompatible combination. However, it is seen at once that all of the carbonates are in the bicarbonate form and while readily soluble in the cold are readily decomposable on the application of heat. This water supply for the two cities was brought into use about 1884. It comes from the drift at about 165 feet below the surface. Since the first development of this type of water in 1884 the local area has been greatly extended. As a result of a study, about 1900 to 1905, of the water supplies of the Illinois Central, the Chicago & Alton and the Big Four Railroads between Peoria and Indianapolis an area producing such waters could be roughly indicated by drawing a line from a point somewhere between Paxton and Gilman on the Illinois Central Railroad, proceeding westward to include Normal, thence southward through the center of Bloomington somewhere between the Chicago & Alton junction and the pumping station of the Big Four Railroad near Center Street, thence south and east to include Bement, Tolono, Philo, Veedersburg, Ind.,

[1] Read before the Illinois Section, April 17, 1918.

and thence westward again to include Hoopeston and Paxton, the starting point. In addition to this area the Illinois State Water Survey has found waters of this type very widely distributed and far more commonly in use than when the supplies came from shallow wells. Bulletin 4 of the Illinois State Water Survey gives the distribution of such waters throughout the state.

In order to understand some of the unusual or unsuspected properties of these waters it will be well to note some of the reactions involved when these waters are in use in steam generators. The first stage in the decomposition of the bicarbonate by heat would of course be the simple reaction:

$$2(NaHCO_3) = Na_2CO_3 + CO_2 + H_2O.$$

However, a study of the actual conditions in the boiler showed that the reaction did not stop here, but a partial hydrolization of the sodium carbonate occurred, thus:

$$Na_2CO_3 + H_2O = NaHCO_3 + NaOH.$$

It will thus be seen that the residual water within the boiler becomes an active reagent for the precipitation of fresh incoming bicarbonates, thus indicating why such waters are self-purging and develop no scale whatever within the boilers. In this discussion, however, the author wishes to call attention to another reaction which accounts for the liberation of ammonia as a gas along with the steam: thus:

$$NaOH + NH_4Cl = NaCl + NH_3 + H_2O$$

Now a word as to the extent to which ammonia may be delivered under the conditions such as are found in the local water supply. If we take, for example, the local power station of the Illinois Traction System, which uses approximately 100,000 gallons of water per day, then on the basis of 0.1 pound of ammonia as NH_3 per 1000 gallons of water, the output would be 10 pounds per day or in the form of ammonium carbonate, 50 pounds daily. Of course, upon cooling, a combination of the ammonia and the carbon dioxide occurs forming the ammonium carbonate salt. Evidence of this is occasionally shown in the complete stoppage of risers in dwellings where the steam has been shut off for some time. This phenomenon has already been reported to this Association and is illustrated by photograph in the *Proceedings* of the Association for 1911, page 61.

This brings us directly to an explanation for a serious corrosive

action which occurs in the heating system of the University, especially in connection with the brass parts of the steam traps to the radiators. The number of these parts thus affected would have to be expressed by 3 figures, but no very exact data are at hand showing the approximate number.

In making a study of the conditions that accompany these failures, it was found that in those buildings where the return water was most strongly impregnated with ammonia, the corrosive action was greatest. These variations in the content of ammoniated condensate that accumulates in certain buildings to a greater extent than in others is a peculiarity that is found to exist also with the variation in content of carbon dioxide gas that accumulates in the radiators.

So far no explanation for these variations has been found, other than that due to their place on the line or the method of taking off the steam supply from the mains. These features however are not essential to the main fact that the condensation water becomes sufficiently impregnated with ammonia to become a strongly corroding reagent for brass.

SOCIETY AFFAIRS

ADDITIONS TO MEMBERSHIP

Active

Sylvester Quayle Cannon, Manager Water Works, Salt Lake City, Utah.

Cornelius M. Crowley, Registrar Water Department, St. Paul, Minneapolis.

Homer V. Knouse, Metropolitan Water District, Omaha, Nebraska.

Edgar A. Rossiter, Civil Engineer, Chicago, Illinois.

William M. Willetts, Murphysboro Water Works, Electric and Gas Company, Aurora, Illinois.

Corporate

Board of Water Commissioners, Glens Falls, N. Y.

DEATHS

John H. Decker, elected member July 18, 1907; died October 10, 1918.

Holly, Ira A., elected member March 29, 1881; Honorary Member; died September 19, 1918.

William F. Woodburn, elected member June 24, 1903; died September 16, 1918.

ROLL OF HONOR

ANDERS, F. L., Captain, Construction Division, U. S. A., Camp Dodge, Iowa.

BAIR, MAURICE Z., Captain, Construction Division, U. S. A., Washington, D. C.

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DALLYN, F. A., Captain, Canadian Expeditionary Forces, Siberia.

EVERETT, CHESTER M., Captain, Sanitary Corps, U. S. A., Fort Oglethorpe, Georgia.

EVINGER, M. I., Captain, Quartermaster Corps, in charge Utilities, Camp Dodge, Iowa.

GREGORY, JOHN H., Captain, Sanitary Corps.

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JOHNSON, EDGAR W., 5th Pioneer Infantry, A. E. F., France.

KELLY, EARL W., Engineer, American Expeditionary Force.

LEVY, A. G., Captain, Quartermaster Corps, U. S. A., Camp McArthur, Texas.

RACE, JOSEPH, Captain Canadian Army, Hydrological Corps, Russia.

STOVER, FREDERICK H., First Lieutenant, Company B, 26th Engineers, A. E. F.

TROW, LINDEN C., Quartermaster Corps, Utilities Division, Camp Grant, Illinois.

JUNIOR ROLL OF HONOR

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HEERMANS, JEROME T. (son H. C.), Lieutenant 25th Field Artillery, Camp McClellan, Anniston, Alabama.

HEERMANS, JOSEPH F. (son H. C.), 36th Prov. Squad., Joyce, Wyoming.

HENDERSON, ERNEST M. (son C. R.), Second Lieutenant, Infantry, St. Louis, Mo.

WILLIAMS, ALLEN H. (son H. L.), 6th U. S. Coast Guard, Battery Barge Office, New York.

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